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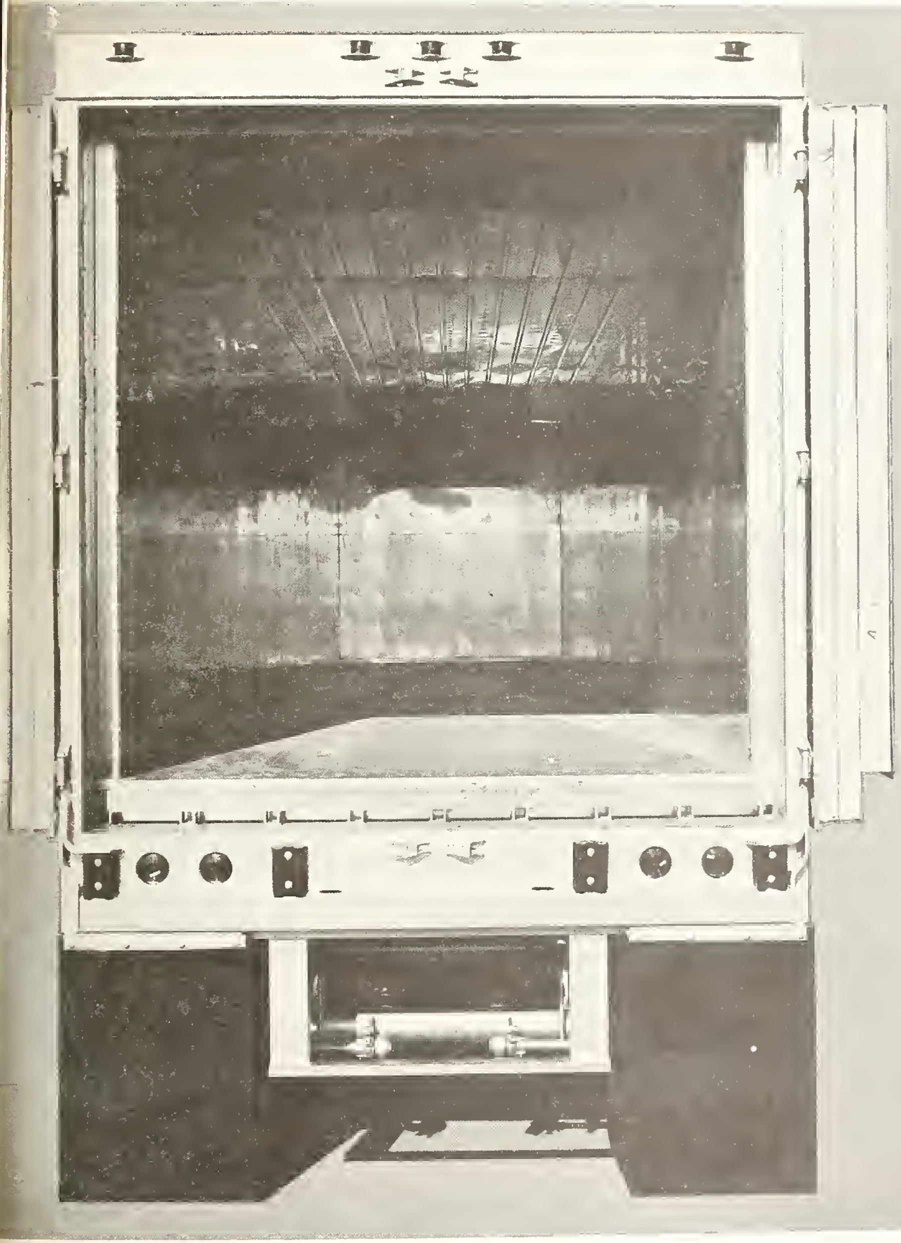
THE COLD-WALL TRAILER



Maintaining Frozen Food Below Zero

MARKETING RESEARCH
REPORT NO. 540

U. S. DEPARTMENT OF AGRICULTURE
AGRICULTURAL MARKETING SERVICE
TRANSPORTATION AND FACILITIES RESEARCH DIVISION

PREFACE

This study is part of a broad program of research by the Agricultural Marketing Service to improve the design and performance of transportation equipment used in the movement of agricultural products. The overall objectives are to improve the marketing of farm products and to hold down its costs.

Time-temperature tolerance tests conducted by the Agricultural Research Service, U. S. Department of Agriculture, have shown what happens to original flavor, color, texture, and vitamin content when frozen food is held at 10° F. 20° F., or higher. These tests have led to a proposal by the Association of Food and Drug Officials of a zero-degree requirement for frozen food.

Previous studies by industry and the U. S. Department of Agriculture indicate that many refrigerated trailers now in service cannot maintain the required 0° F. temperature throughout the load.

This report covers one of several tests to determine the best and most practical combination of equipment and method of operation to maintain the load at 0° F. in transit.

Cooperating in the test were Ore-Ida Potato Products, Inc.; Utility Trailer Manufacturing Co.; and Thermo-King Corporation.

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Washington, D. C. June 1962

THE COLD-WALL TRAILER
MAINTAINING FROZEN FOOD BELOW ZERO

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SUMMARY

Two tests were conducted to compare the refrigerating performance of a "cold-wall" trailer with that of a conventional trailer in transporting frozen food. The cold-wall trailer is a new type in which a blanket of cold air is maintained on all sides of the load of food.

In the first test, the cold-wall trailer generally maintained the load of frozen french fried potatoes below 0° F. throughout the 3 days in transit. The conventional trailer could not be used for comparison because the refrigeration unit did not operate effectively during parts of the test.

In the second test of the cold-wall trailer, the temperatures of the frozen french fried potatoes were consistently lowered. The average temperature of the load was reduced from 7° F. at loading to 0° at unloading, while the temperature of the warmest box decreased during this same period from 14° to 7°.

The conventional trailer in the second test, although equipped with the same refrigeration unit as the cold-wall trailer, was unable to keep the product from warming up. The average product temperature increased from 5° F. at loading to 13.8° at unloading, while the maximum product temperature increased from 16.3° to 27.3°.

Data for the conventional trailer in the second test indicate an average loss in quality estimated at four times the normal loss which would have occurred had the temperature of the potatoes been maintained at 0°. The storage life of potatoes in the conventional trailer was reduced, on the average, an estimated 10 days. The warmest box averaged 20.9° F. during the test, and its exposure to temperatures above 0° reduced the storage life of the potatoes by roughly 70 days, or 20 percent of the total storage life of 1 year.

The warmest box in the second test of the cold-wall trailer averaged 7.9° F. during the 3 days in transit. The storage life of the warmest box was reduced an estimated 6¼ days by exposure to temperatures above zero. This box, however, was loaded at 8.7° and was cooled during transit to 7.1°.

A comparison of the fuel consumption of the refrigerating units was made. The two units are practically the same. The unit in the cold-wall trailer ran 40 percent of the time at high speed, and fuel consumption averaged .7 gallon per hour. The unit in the conventional trailer ran 66 percent of the time at high speed, and fuel consumption averaged .8 gallon per hour. This larger fuel consumption was due primarily to the fact that the unit in the conventional trailer operated longer at high speed.

These tests show that the cold-wall trailer could maintain a frozen product at an average temperature of about -2.5° F. (below zero) provided the product is loaded at a temperature of 0° or below. When the product was loaded at an average of 7° F., the cold-wall trailer, given sufficient time, reduced the average temperature of the product to 0°.

The new cold-wall trailer design will help carriers to maintain frozen foods closer to 0° than was heretofore possible in most trailers. Improvements in design and construction have increased the effectiveness of the refrigerating equipment, so that lower temperatures can be achieved without an increase in the size or capacity of the equipment. In addition, the refrigerating unit in the cold-wall trailer operated less time at high speed than the unit in the conventional trailer (a difference of 19½ hours during the 80½ hours of the test). This indicated that fuel operating cost and perhaps also general maintenance cost would be less for the unit in the cold-wall trailer.

BACKGROUND OF STUDY

Time-and-temperature tolerance tests conducted by the U. S. Department of Agriculture 1/ have shown that loss of quality occurs in frozen vegetables when exposed to temperatures above zero. Generally, losses of chlorophyll (green pigment) and vitamin C are useful measures of loss of quality.

But losses of quality are not limited to loss of vitamin C and chlorophyll. Dark brown slices of frozen peaches, discolored strawberries, raspberries with color blended into the syrup, and dull brown cherries with tough skins are common examples of poor quality.

Rate of loss of vitamin C is many times faster at 10° F. than at 0°, and many times faster at 20° than at 10°. The following combinations of time-temperature exposures have been found to result in approximately equivalent losses of quality: One year at 0° F.; 6 months at 5°; 3 months at 10°; 6 weeks at 15°; 3 weeks at 20°; 10 days at 25°; and 5 days at 30°. 1/

However, it has been estimated roughly that only about one of every six refrigerated trucks now in frozen food service can hold the food at zero. A major problem in holding zero throughout the load of frozen food is in

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1/ "Protect Frozen Foods From Temperature Damage." U. S. Dept. Agr., Agr. Res. Serv., ARS 74-9, revised Sept. 1959.

distributing cold air. Even though the capacity of the refrigerating equipment may be adequate to hold zero, the product temperature throughout the load of frozen food may not be held at that level.

Many refrigerating units now in service have the capacity to hold well-insulated trailers at zero. Thick insulation slows down the rate of heat transfer through the walls, and the refrigeration requirements are therefore reduced; but, unless cold air is distributed so that the heat is picked up before it reaches the product, a gradual warming takes place. An example of this was observed in a trailer loaded so that the cold air circulated only above the load; the bottom of the load gradually warmed up while the top stayed cold.

Since the proposal of a 0° F. code by the Association of Food and Drug Officials of the United States, the frozen food industry has begun a re-evaluation of its equipment and operating procedures. Interest in improvement of equipment, in new designs, and in research is widespread. The Frozen Foods All-Industry Coordinating Committee has recommended voluntary policing of quality to encourage use of better equipment.

The continuing study by AMS of designs in trailers under actual operating conditions is evaluating new equipment, showing what progress has been made in keeping frozen food at zero, and indicating what designs are best and the direction which improvements in designs should take.

The study on which this report is based was conducted to evaluate a new type of trailer design, based on the principle of enclosing the load on all sides with a blast of cold air, thereby picking up the heat transmitted through the trailer walls, floor, and ceiling before it reached the product. A companion trailer of conventional design was used for comparison in each test.

DESCRIPTION OF TRAILERS IN TEST I [2]

Trailer A

Body: Perimeter-airflow (cold-wall) design provided space between inner aluminum walls and insulation for circulation of cooling air. The trailer was equipped with flat aluminum sidewalls and a dry freight floor 1-1/8 inches high, with a gutter 1 inch by 1 inch along each sidewall. The following table shows the thickness of the air space and the type and thickness of insulation in the various sections of the trailer.

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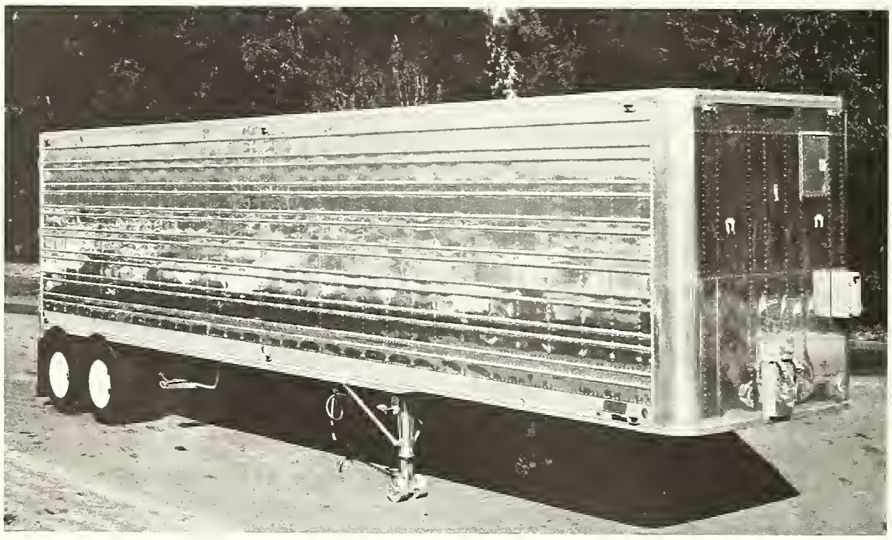
[2] Description based on manufacturer's specifications.

Table 1.--Air space and insulation in trailer A

Location	Thickness of polyurethane foam insulation	Thickness of air space
	Inches	Inches
Floor	6	4
Roof	6	4
Sidewalls	4	1½
Doors 1/	6	1½
Front	4	6

1/ See figures 2 and 3, which show design at doors.



BN-14211

Figure 1.--Cold-wall perimeter-airflow trailer.

Refrigerating Unit: Capacity of the refrigerating unit was rated at about 21,000 B.t.u. per hour at 0° F. trailer temperature and 100° outside air temperature. The diesel-powered unit had an underslung condenser section and remote evaporator section mounted inside the front trailer wall. It operated at high speed (2,400 r.p.m.) until the thermostat setting was reached, and then dropped to low speed at 1,400 r.p.m. The unit operated at high speed and low speed as required to maintain the temperature at the thermostat setting, with a range of -20° to 70° F. All heating and defrosting was by means of a reverse-cycle system. The four-cylinder, V-type, aluminum reciprocating compressor was connected directly to the four-cylinder, four-stroke-cycle, vertical-type diesel engine rated at 26 brake horsepower. The water-cooled engine, with aluminum pistons and chrome nickel alloy cast iron cylinder blocks, weighed about 400 pounds and drove an alternator which provided power for the wo 1/3-horsepower A.C. motors driving the propeller-type evaporator fans. Fan apacity was rated at 600 cubic feet per minute.

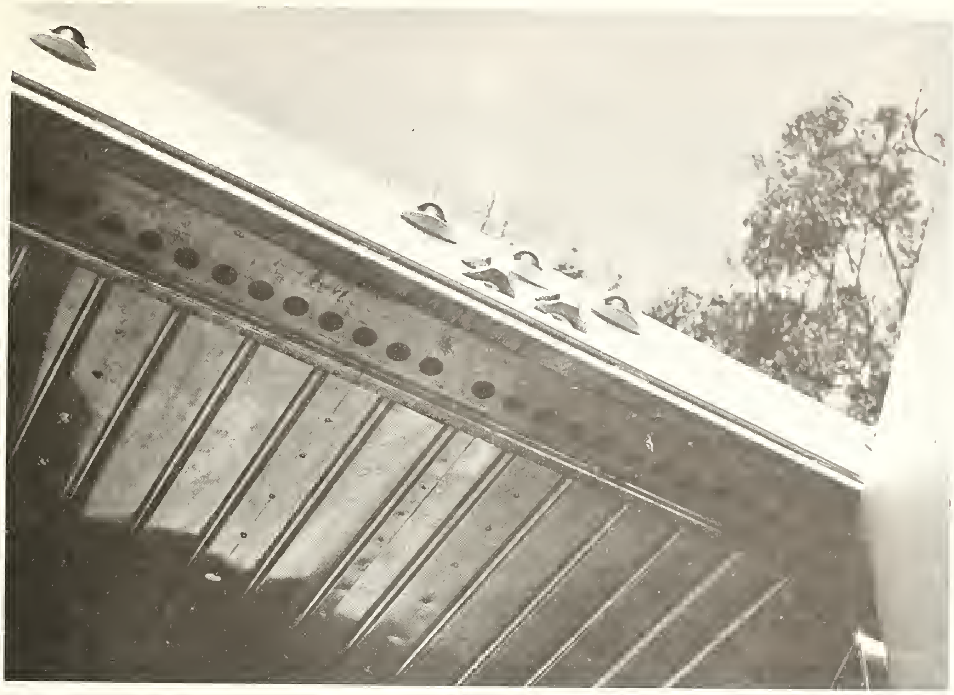

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Figure 2.--Rear of trailer A, showing 2-inch holes in ceiling for air circulation into doors.

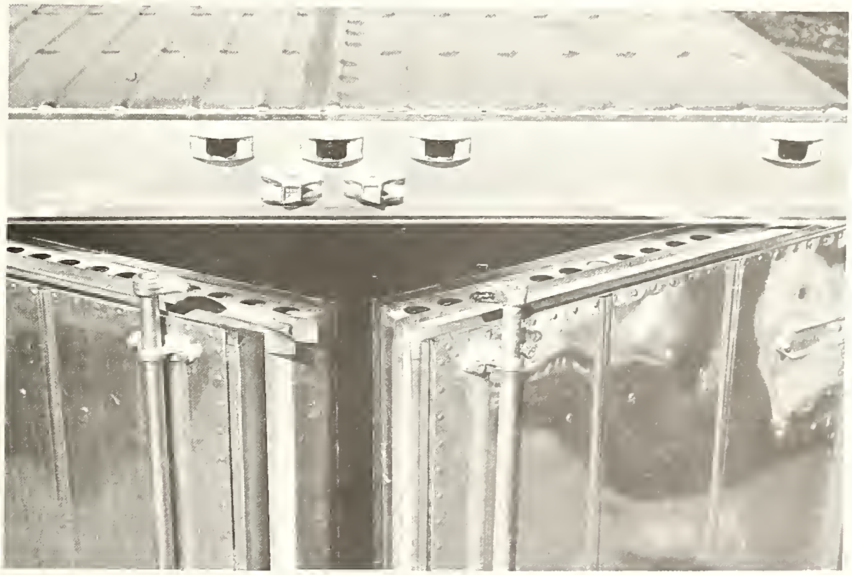
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Figure 3.--Rear of trailer A, showing 2-inch holes in top of doors for air circulation. There are similar holes in the bottom of the door to allow air to return through the floor.

The finned-tube counterflow-type evaporator coil section was 39½ inches high, 58½ inches wide, and 20½ inches deep, and weighed about 315 pounds. The condenser section, which was 28 inches high, 59 inches long, and 35 inches wide, mainly comprised the engine, compressor, condensing coil, and controls, and weighed about 1,250 pounds.

Automatic defrosting was initiated about every 3½ hours by a timer-clock relay circuit which opened the circuit from the alternator to the fan motors, thereby stopping the fans, and threw a reverse-cycle valve. The reverse-cycle transmitted the heat from the condenser coil to the evaporator coil, thereby defrosting the coil. Defrosting continued until a bimetallic switch, mounted on the evaporator coil, reached a preset temperature above freezing. This switch then opened, breaking the defrost relay circuit, completing the defrost cycle, and returning the unit to the thermostatic control.

The refrigerating unit was connected with a 50-gallon fuel tank mounted under the trailer.

Inside and outside trailer dimensions are shown in table 2.

Table 2.--Trailer dimensions

Trailer	Inside dimensions			Outside dimensions			Capacity (cubic feet)
	Length	Width	Height	Length	Width	Height	
A	38'-1"	84"	86"	40'-0"	8'-0"	13'-0"	1910 1/
B	38'-1"	85-3/4"	96-5/8"	40'-0"	8'-0"	13'-0"	2190 2/

1/ Can be fully utilized by tight loading.
2/ Space must be left for air circulation.

Trailer B

Body: The inside and outside dimensions of trailer B are given in table 2. The trailer had ceiling supports for meat rails (actual rails not installed) and a side door 44 inches wide by 82¼ inches high, insulated with 4 inches of glass fiber. There was 4 inches of glass fiber in the rear doors, sidewalls, and roof; 5 inches of foam in the floor with a 1-inch heat vapor barrier, except for 4 inches of foam in the floor back of the support legs.

The wall lining of ¼-inch plastic-coated plywood had ½-inch-deep corrugations on 8 and 10 inch centers running at a 45-degree angle toward the bottom rear of the trailer. The front lining and ceiling lining were ¼-inch plywood covered with smooth plastic. One-fourth-inch plastic-coated plywood with ½-inch-deep vertical corrugations covered the doors. Forty grooves 1 inch by 1 inch on 2-3/4-inch centers ran the length of the extruded aluminum floor. Although not used in the test, two small trap doors in the transition duct above the evaporator coil could be opened for ventilation when the trailer was loaded with fresh fruit or vegetables.

Refrigerating Unit: The capacity of the refrigerating unit was rated at about 19,190 B.t.u. per hour at 0° F. trailer temperature and 100° outside air temperature. The pancake-style unit mounted in the nose of the trailer was powered by a 4-cylinder, liquid-cooled, 4-stroke-cycle, 17-horsepower engine of 2½-inch bore by 3-1/8-inch stroke. This engine used propane as fuel. The compressor was directly connected to the engine, and operated at 2,400 r.p.m. The unit stopped when the trailer temperature reached the thermostat setting, restarting when additional cooling or heating was required.

The four-cylinder, V-type aluminum reciprocating compressor was the same size and type as that used in the refrigerating unit in trailer A.

The aluminum-finned tube counterflow-type evaporator coil, with a face area of approximately 710 square inches, was somewhat smaller than that in trailer A, which had an effective face area of about 1,000 square inches.

The total weight of the unit was roughly 1,024 pounds, not including the 58-gallon propane fuel tank. Heating and automatic defrosting were accomplished through the same reverse-cycle system as that used in trailer A.

The blast air was discharged through four canvas ducts, 9 inches wide by 5 inches high by 28 feet long, which ended about 7 feet, 5 inches ahead of the rear of the trailer. Evaporator fan delivery was rated at 2,200 cubic feet per minute. Figure 5 shows a baffle which prevents cold air from returning directly to the evaporator coil over the top of the load. Arrows shown represent cold air returning through the space at the nose of the trailer after having passed under the baffle.

PROCEDURE IN TEST I

The refrigerating units on both trailers were started at 1:15 p.m. before leaving Ontario, Oreg., and at that time the thermostats were set at -5° F. (below zero). The trailer then proceeded to Burley, Idaho, for loading, trailer A making a short stop at Boise for installation of a clock to time the high-speed operation of the unit. The refrigerating unit had precooled the trailer to -2.5° F. (below zero) before loading began at Burley, Idaho. The refrigerating unit in each trailer was shut off during loading to reduce condensation inside the trailer and frosting of the evaporator coil. Twenty-three copper-constantan thermocouples were installed in each trailer, seventeen of which were placed inside the boxes of frozen french fried potatoes to indicate product temperatures. Four thermocouples were used to indicate temperatures of the air inside the trailer. A separate thermocouple was placed at the thermostatic control bulb to show the temperature of the air returning to the unit, and another was placed inside the outlet duct to indicate the air temperature leaving the evaporator coil.

During loading, thermocouples were placed in selected boxes distributed throughout the trailers (figs. 4 and 5). Those thermocouples used to show product temperatures were placed inside the center package in each box of frozen product. The box was then sealed and the thermocouple taped in place. Each trailer was loaded with 1,260 boxes of crinkle-cut french fried potatoes, making a total load of 40,005 pounds, with loading distribution as shown in figures 4 and 5.

After loading, the trucks proceeded together to Cincinnati, Ohio. Temperatures recorded are shown in the tables in the appendix. Before each set of data was recorded, the potentiometer was calibrated in an ice bath prepared for this purpose, and any minor corrections necessary were made in the readings. It was noted at unloading that each thermocouple had remained in its proper location during the test.

Handling of the packages was minimized during the loading and unloading operations. During loading, fork trucks picked up the palletized loads in the warehouses and moved them directly into the trailer, where the packages were stacked in place. During unloading, the packages were palletized inside the trailer and then moved by fork truck directly into the warehouse.

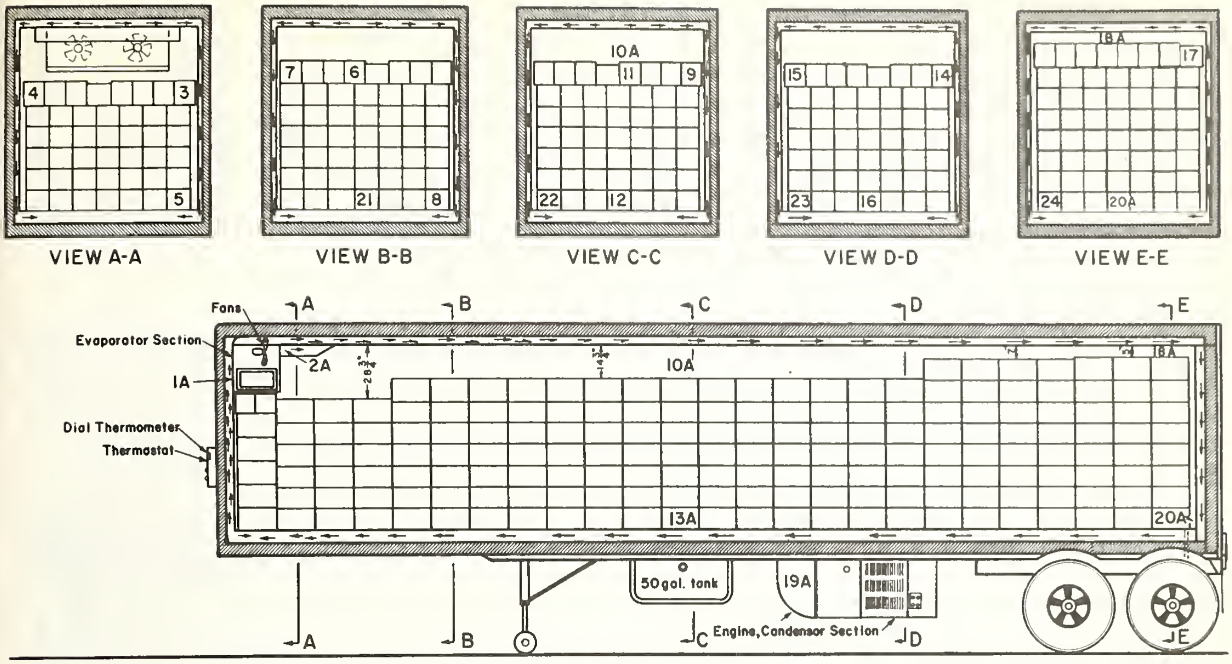
RESULTS OF TEST I

On June 15, the day before loading, a precooling test of both trailers was run for approximately 5 hours inside an open-end shed. The units were both started at 10:30 a.m. and ran continuously at high speed throughout the precooling test, without defrosting. The temperature was reduced from 79° F. to -1° in the cold-wall trailer in just 4½ hours, while the temperature in trailer B fell from 87° to 6° during the same period. The curves in figure 6 indicate that the net effective refrigeration 2/ is slightly greater in trailer A, the cold-wall trailer, than in trailer B.

The refrigerating units were started on both trailers at 1:15 p.m. before they left Ontario, Oreg. The air temperature inside both trailers had fallen to -2.5° F. before loading began at Burley, Idaho. Most of the frozen french fried potatoes in trailer A were consistently held below zero throughout the test. The overall average commodity temperature decreased 1° during the test, averaging -3.4° just before unloading, and -2.6° for the overall 3-day transit test. The maximum commodity temperature, which was consistently at the rear top corner of trailer A, was 3.1° at unloading and averaged 2.8° for the overall transit test. The minimum commodity temperature in trailer A averaged -6.7° for the overall test, was -7.9° at unloading, and was consistently found at the top front quarter section of trailer A. The maximum commodity temperature at the top of the load increased 1.5° while the maximum bottom commodity temperature increased 2.6° during the 3-day test. The maximum bottom commodity temperature, which was consistently at location 16, the center rear quarter section, averaged 2.1°, while the minimum bottom commodity temperature during the same 3-day period averaged -5.4° at the front corner of trailer A.

The spread in commodity temperatures increased in trailer A during the test from 6.8° F. to 11.0°. Figure 7 shows that the extremes usually were found on the top of the load.

2/ "Net effective refrigeration" is used here to represent refrigeration unit capacity less total trailer heat gain due to conduction, infiltration, and radiation.

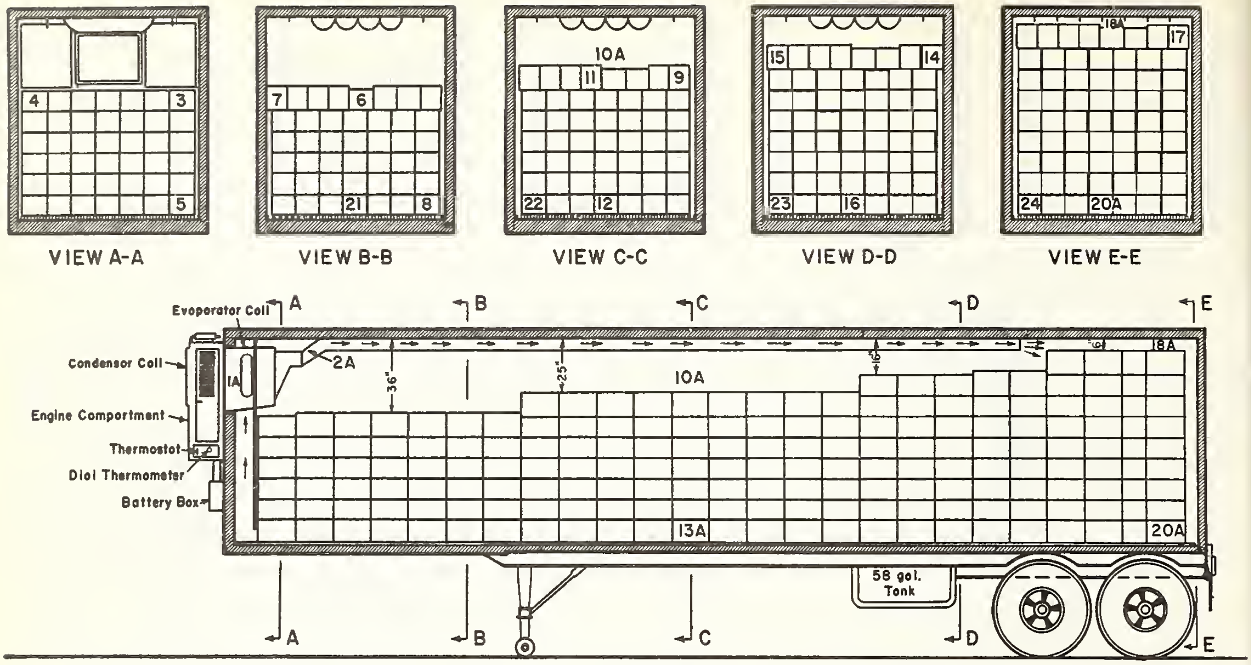


TRAILER A

U.S. DEPARTMENT OF AGRICULTURE AMS NEGATIVE 61-61(8) AGRICULTURAL MARKETING SERVICE

No.	POSITION	No.	POSITION
1A	Return air	12	½ length, bottom, center
2A	Blast air	13A	½ length, bottom, center, air
3	Front, top, right side	22	½ length, bottom, left side
4	Front, top, left side	14	3/4 length, top, right side
5	Front, bottom, right side	15	3/4 length, top, left side
6	¼ length, top, center	16	3/4 length, bottom, center
7	¼ length, top, left side	23	3/4 length, bottom, left side
8	¼ length, bottom, right side	17	Rear, top, right side
21	¼ length, bottom, center	18A	Rear, top, center, air
9	½ length, top, right side	19A	Outside air (ambient)
10A	½ length, top center, air	20A	Rear, bottom, center, air
11	½ length, top, center	24	Rear, bottom, left side

Figure 4.--Location at which air and frozen french fried potato temperatures were taken in trailer A. Boxes show the loading distribution through the trailer. Clearance around the load is unnecessary as cold air is circulated through the walls, floor, and ceiling.



U.S. DEPARTMENT OF AGRICULTURE TRAILER B AMS NEGATIVE 62-61(8) AGRICULTURAL MARKETING SERVICE

No.	POSITION
1A	Return air
2A	Blast air
3	Front, top, right side
4	Front, top, left side
5	Front, bottom, right side
6	¼ length, top, center
7	¼ length, top, left side
8	¼ length, bottom, right side
21	¼ length, bottom, center
9	½ length, top, right side
10A	½ length, top, center, air
11	½ length, top, center
12	½ length, bottom, center
13A	½ length, bottom, center, air
22	½ length, bottom, left side
14	3/4 length, top, right side
15	3/4 length, top, left side
16	3/4 length, bottom, center
23	3/4 length, bottom, left side
17	Rear, top, right side
18A	Rear, top, center, air
19A	Outside air (ambient)
20A	Rear, bottom, center, air
24	Rear, bottom, left side

Figure 5.--Locations at which air and frozen french fried potato temperatures were taken in trailer B. Boxes show the loading distribution through the trailer.

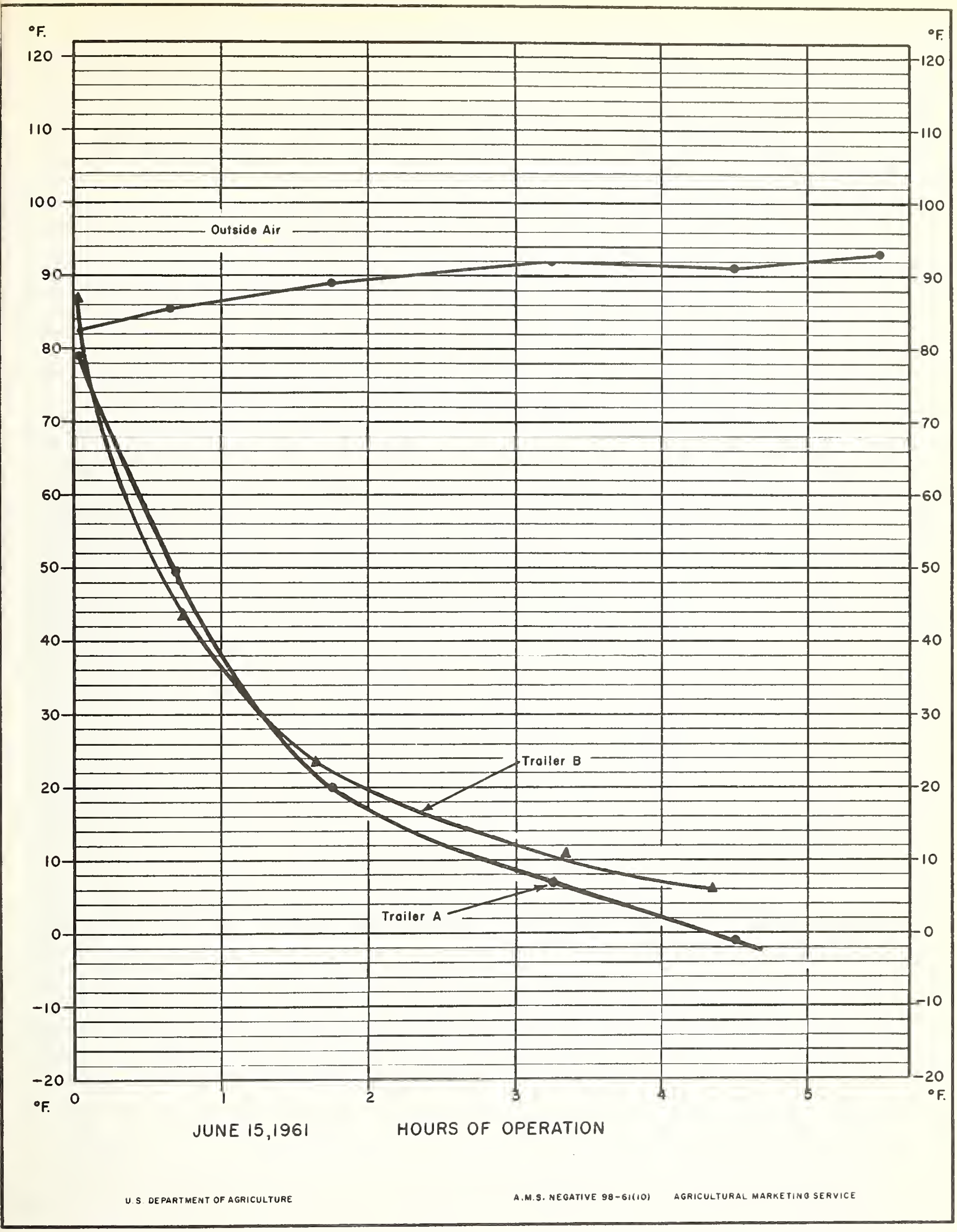


Figure 6.--Average air temperatures during precooling pulldown test of trailers A and B.

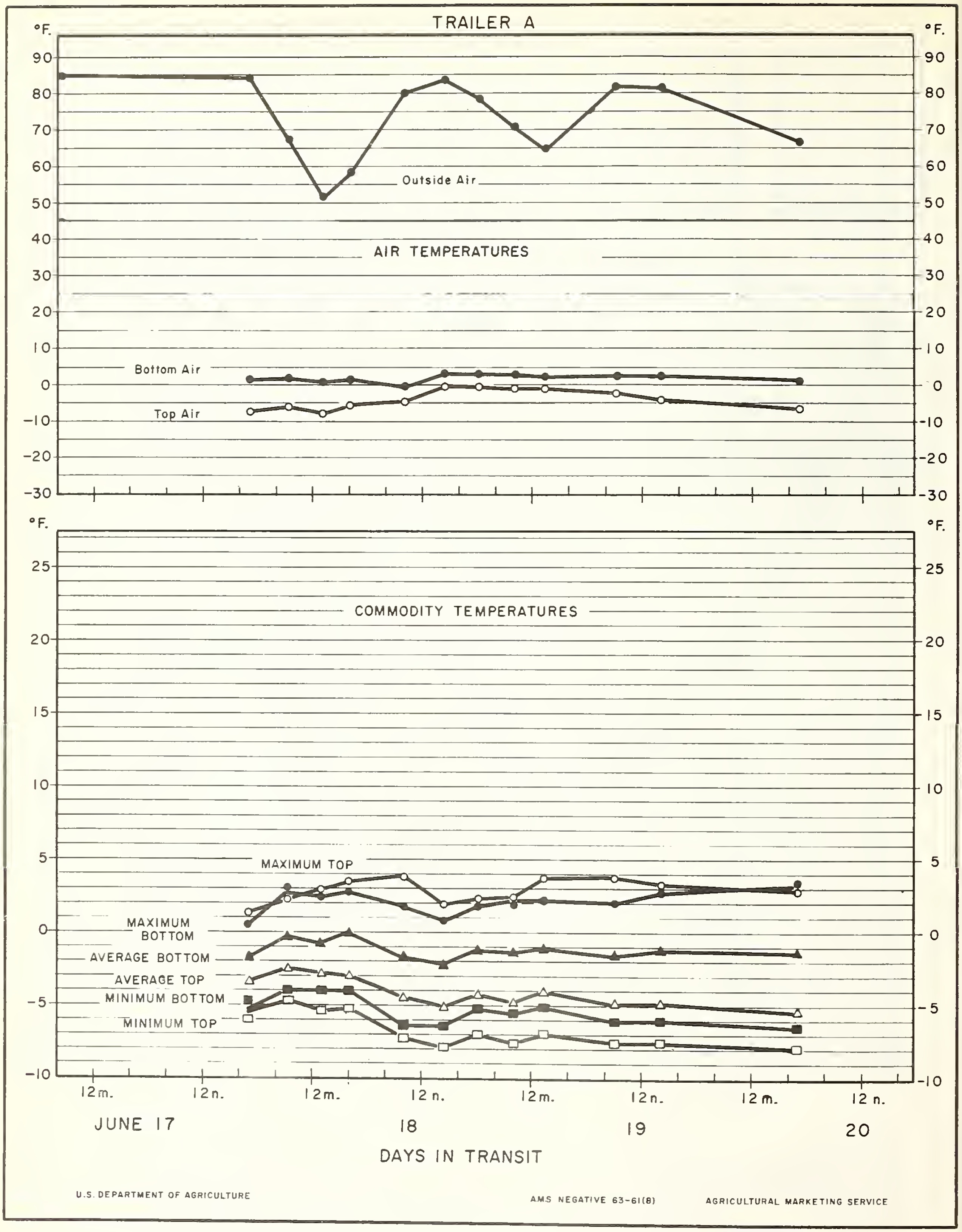


Figure 7.--Air and commodity temperatures in trailer A.

Generally, the temperatures in trailer B steadily increased during the first half of the test, reaching a high at 1:30 a.m. on June 19, and decreased during the latter half of the test.

Comparative figures on quality loss can be computed by using the loss at 0° as a standard in comparison with time-temperature quality loss equivalents. A report by the U. S. Department of Agriculture (see footnote 1, p. 2) indicates that the quality loss rate for frozen vegetables at 5° is twice that at 0°; that the rate at 10° is 4 times that at 0°; the 15° rate 8 times that at 0°; the 20° rate 16 times that at 0°. These equivalent rates of quality loss are only approximations and vary with each commodity; however, they can serve as a yardstick for comparison purposes and shed some light on what loss in quality may be expected.

A study of the average commodity temperature in trailer A reveals that this average remained well below zero throughout the test. The quality loss then would be estimated to be equal to or less than that during storage at zero.

However, that was not the case in trailer B. The following table was prepared by breaking up the temperature range into 5-degree increments and totaling up the time at which the average commodity temperature of trailer B was within each range during the test. The quality loss rate ratio for each 5-degree range, using 0° as a standard, is shown in column 3. The equivalent time required at 0° for the same degree of quality loss is shown in column 4. The total estimated quality loss during the test was equivalent to that during 257 hours of storage at zero.

Table 3.--Estimated quality loss in trailer B

Temperature range	Exposure	Quality loss rate	Equivalent time at 0° F.
	Hours	Ratio	Hours
-2° to +2°	16.0	1	16.0
+3° to +7°	21.5	2	43.0
+8° to +12°	27.5	4	110.0
+13° to +17°	11.0	8	88.0
Totals	76.0	---	257.0

As the test was only 76 hours long, it is apparent that each hour in transit was equivalent to 3½ hours at 0° F. The average storage life at zero was reduced by about 7½ days (181 hours) by exposure of the product to temperatures above zero.

The quality loss herein discussed is used as a yardstick for comparison purposes only, and was not determined by an actual analysis of physical changes in the product.

The design of trailer B cannot be compared to that of trailer A because the refrigeration unit in trailer B did not operate effectively during parts of the test and the load was not well distributed. Automatic defrosting apparently did not operate during part of the test. A large amount of ice on the evaporator coil restricted airflow and thereby considerably reduced the effective refrigeration from about 10:00 a.m. to 10:00 p.m. on June 18, at which time the unit was manually defrosted. The nine-high stacks of boxes at the rear of the trailer apparently restricted the air circulation in this area.

The temperatures in trailer B are discussed primarily as an illustration of the effects of the adverse conditions. In trailer B, the overall average commodity temperatures increased from 3.2° to 13.6°. The temperature was 8.6° at unloading, and averaged 8.2° for the overall 3-day transit test.

The maximum commodity temperature in trailer B increased steadily to 25°, and was 23.5° at unloading. It was found at locations Nos. 17 and 22. The maximum bottom commodity temperature, at location No. 22, averaged 18.6° and the maximum top commodity temperature, at location No. 17, averaged 17.3° F. during the test. The minimum top commodity temperature, during the same period, averaged 0.7°, and was -0.2° at unloading. It was generally located at positions Nos. 6 and 11. The minimum bottom commodity temperature averaged 7.7° during this period and was 9.3° at unloading. It was generally found at position No. 16 in trailer B.

The commodity temperature spread increased in trailer B from 12.2° to 25.8°, averaging 19.2° for the overall test.

The results indicate that the 1-inch by 1-inch floor grooves did not permit an adequate amount of air to flow under the load. Also, apparently the ½-inch sidewall corrugations did not provide enough air space. The use of floor racks would provide the needed additional air channels under the load.

Fuel Consumption in Test I

The fuel tank of each trailer was filled before the units were started at Ontario, Oreg. Trailer A was refueled once in transit and again after unloading at Cincinnati. This unit consumed 62.3 gallons of diesel fuel and averaged approximately .72 of a gallon of fuel per hour for the entire trip. Although the thermostat was set at -5°, this unit cycled between high and low speed during most of the trip, running an average of 54 percent of the time at low speed, which resulted in lower fuel consumption.

Trailer B was refueled four times in transit and required an estimated 29 gallons to fill the tank after unloading. This unit averaged about 2.1 gallons of propane per hour and used approximately 183 gallons for the entire trip. Due to mechanical difficulty, this unit operated at high speed throughout the test and the fuel consumption was therefore greater than would normally be expected.

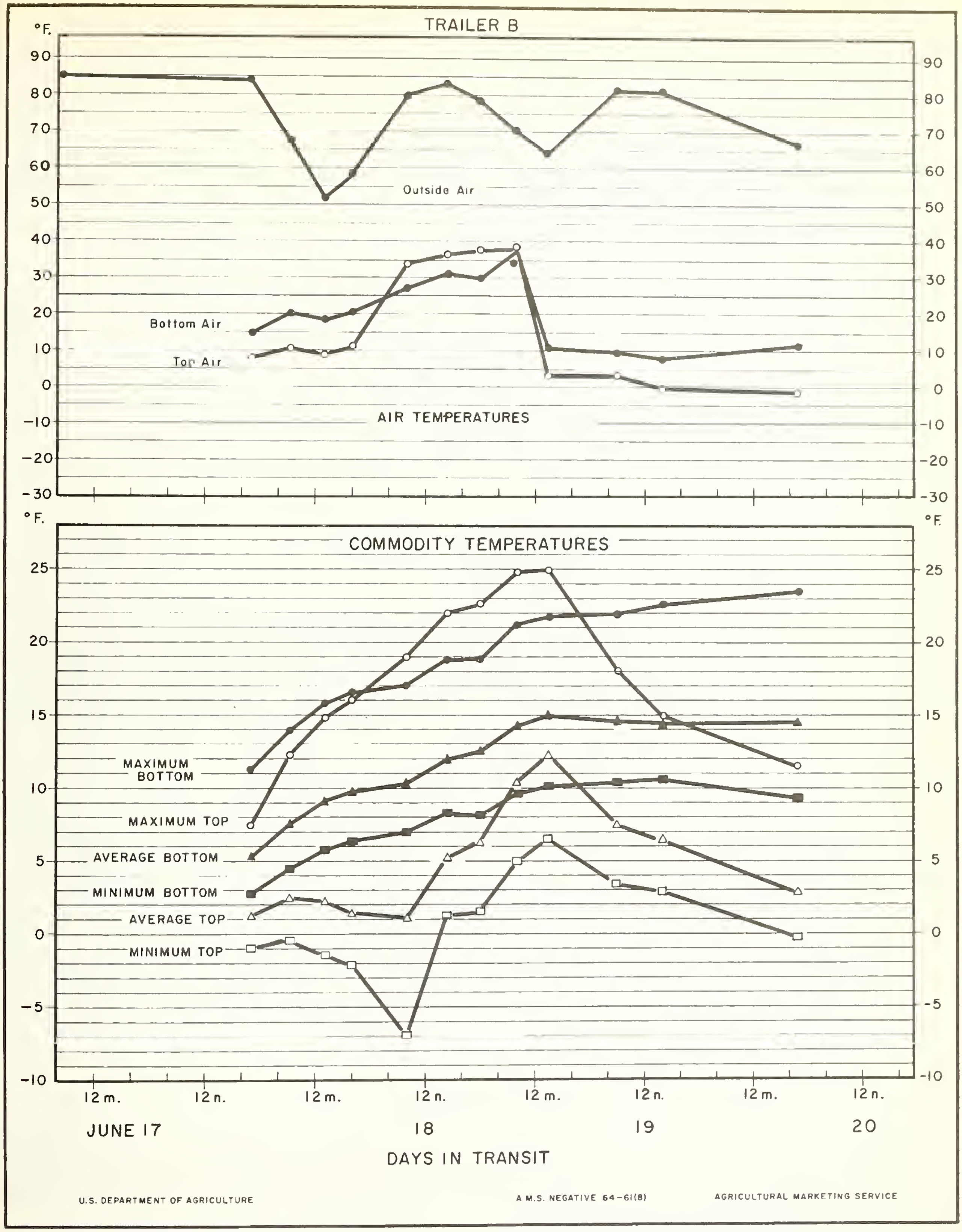


Figure 8.--Air and commodity temperatures in trailer B.

Table 4.--Fuel consumption of refrigeration units

Trailer A					Trailer B			
Location	Operating hours		Fuel Cons.	Avg. fuel cons. per hour	Location	Operating time	Fuel cons.	Avg. fuel cons. per hour
	At high speed	At low speed						
	Hours	Hours	Gal.	Gal.		Hours	Gal.	Gal.
Gothenburg, Nebr.	20.6	22.8	29.8	.69	Little America, Wyo.	21.9	48.1	2.2
					Gothenburg, Nebr.	20.0	43.0	2.2
					Ottumwa, Iowa	15.2	32.0	2.1
Cincinnati, Ohio	19.6	24.2	32.5	.74	Batesville, Ind.	15.1	31.0	2.1
					Cincinnati, Ohio	13.1	29.0	2.2
Overall	40.2 (46%)	47.0 (54%)	62.3	.72		85.3	183.1	2.1

DESCRIPTION OF TRAILERS IN TEST II

Trailer C

Trailer C and trailer A were, for practical purposes, identical. Both trailers were new, were constructed according to the same specifications, and were of the perimeter-airflow, cold-wall design. A complete description of these trailers and the refrigerating units has been presented in the description of trailer A, p. 3.

Trailer D

Body: The inside length of trailer D was 39 feet 2 inches; inside width, 87 inches; inside height, 87 inches; cubic feet, 2,060. The inside lining was ¼-inch plywood. The trailer had 4 inches of glass fiber, with a vapor barrier, in the sides, ends, ceiling, and floor, and an extruded aluminum floor with 1¼-inch-deep grooves. It did not have floor racks.

Refrigerating Unit: Trailer D had the same type of underslung refrigerating unit as trailers A and C. One canvas air duct, 66 inches wide and 31 feet 5 inches long, extended from the evaporator coil within 6 feet of the rear of the trailer.

PROCEDURE IN TEST II

The procedure followed in test II was generally the same as in the first test. The thermostats on both trailers were set at -5° F. The refrigerating unit in trailer C was started at 4:25 p.m., and precooled the trailer to -.5°. The refrigerating unit in trailer D was started at 6:50 p.m., and precooled the trailer to 3°. As in the first test, in each instance the refrigerating unit was shut off during loading. Loading of trailer D began at 9:10 p.m., and of trailer C at 12:25 the following morning, August 26.

Trailer C was loaded with 1,790 cases of various types of frozen potatoes, totaling 38,747 pounds, and trailer D was loaded with 2,067 cases, totaling 39,529 pounds. **Figures** 11 and 12 show the boxes stacked in trailers C and D.

Twenty-three thermocouples were installed in each trailer in the same manner and pattern as in the first test. Figures 9 and 10 indicate the position of the thermocouples and the distribution of the loads inside trailers C and D.

Loading was completed at 3:40 a.m. and the trailers then proceeded together to Cincinnati, Ohio. Temperature readings were taken at intervals of 3 to 6 hours when the trailers stopped for fuel. Trailer C unloaded at three points in Cincinnati, and trailer D partially unloaded at two points in Cincinnati and then proceeded to Dayton, Ohio. The test was therefore concluded after arrival in Cincinnati, before the trailers separated shortly before unloading.

RESULTS OF TEST II

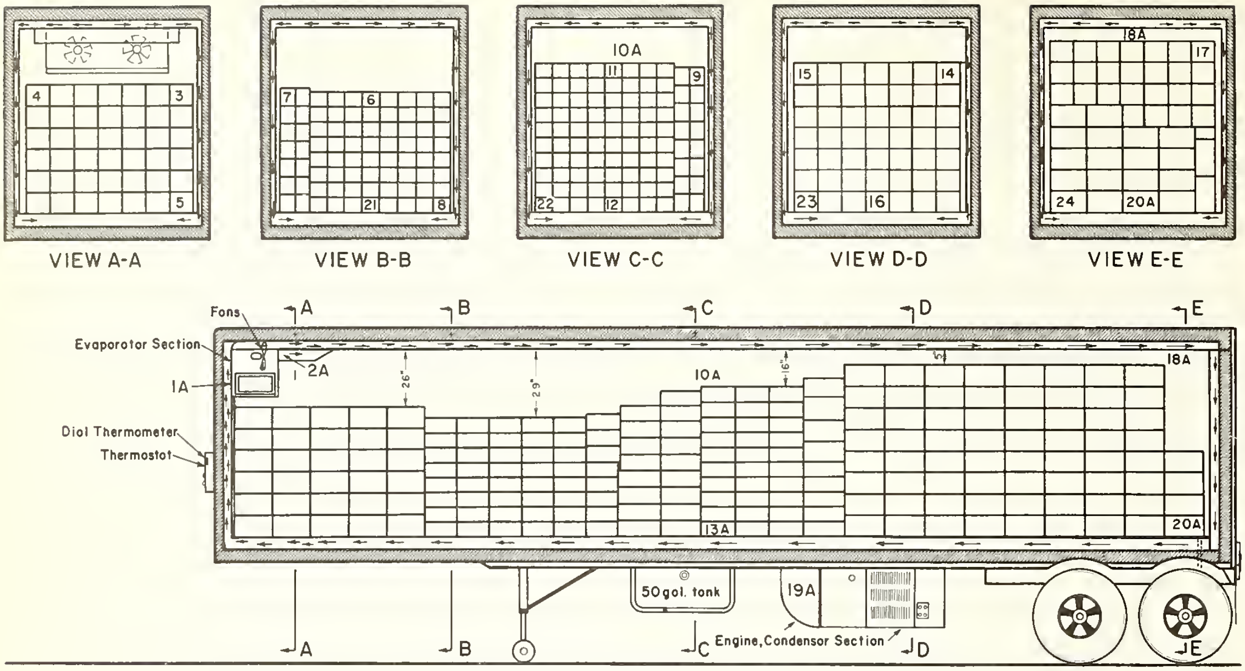
Air and commodity temperatures of trailers C and D during transit are shown graphically in figures 13 and 14. The temperatures in the cold-wall trailer generally decreased throughout the second test. However, because the load was warmer at the start, the temperatures were naturally higher than those in the first test of this type of trailer. The overall average commodity temperature in the cold-wall trailer designated as trailer C fell from 6.9° following loading to -.1° at unloading, and averaged 2.4° for the entire test. The maximum commodity temperature was reduced from 14° at loading to 7° at unloading; it averaged 8.7° for the overall test, and was usually found at either the bottom rear quarter length position or at the top rear corner of the trailer. The minimum commodity temperature in trailer C averaged -3.7° overall, and decreased during the test from 3.5° following loading to -7.7 before unloading.

The maximum top commodity temperature fell rapidly to 7° in trailer C after loading, and was then generally maintained at or near this temperature throughout the test. The maximum bottom commodity temperature also fell rapidly after loading and was maintained generally near 8°.

The spread in commodity temperatures increased from 10.5° after loading to 15.4° and then was reduced to 14.8° at unloading. The highest and lowest temperatures were usually at the top of the cold-wall trailer, as was found in the test of trailer A of the same design.

The temperatures in trailer D generally increased throughout the test. The average top-commodity temperature increased from 6.3° to 7.1° while the average at the bottom increased from 3.6° to 20.5° during the 3-day test. The maximum top-commodity temperatures increased from 16.3° to 23.3° while the maximum at the bottom increased from 12.7° to 27.3° F. during the same period.

The spread in commodity temperatures after loading was 17.6°. It increased during the trip, and was 27.3° at Cincinnati before unloading. The minimum



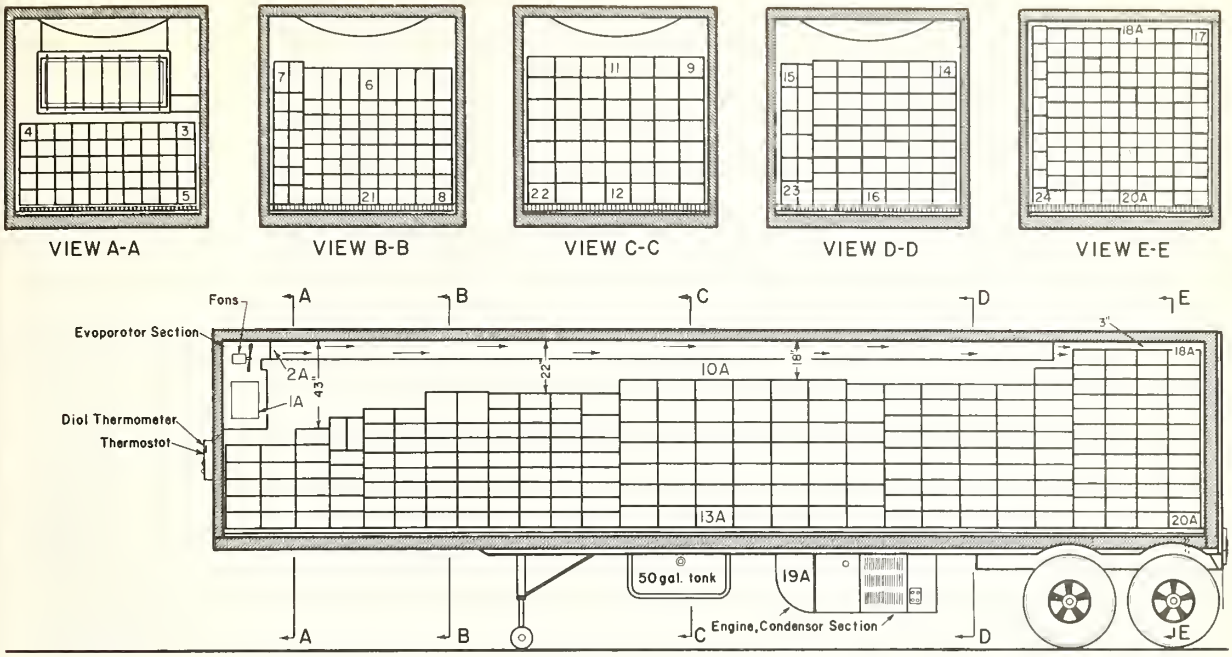
U.S. DEPARTMENT OF AGRICULTURE

TRAILER C

AMS NEGATIVE 95-61(10) AGRICULTURAL MARKETING SERVICE

No.	POSITION	No.	POSITION
1A	Return air	12	½ length, bottom, center
2A	Blast air	13A	½ length, bottom, center, air
3	Front, top, right side	22	½ length, bottom, left side
4	Front, top, left side	14	3/4 length, top, right side
5	Front, bottom, right side	15	3/4 length, top, left side
6	¼ length, top, center	16	3/4 length, bottom, center
7	¼ length, top, left side	23	3/4 length, bottom, left side
8	¼ length, bottom, right side	17	Rear, top, right side
21	¼ length, bottom, center	18A	Rear, top, center, air
9	½ length, top, right side	19A	Outside air (ambient)
10A	½ length, top, center, air	20A	Rear, bottom, center, air
11	½ length, top, center	24	Rear, bottom, left side

Figure 9.--Locations at which the air and frozen fried potato temperatures were taken in trailer C. Boxes show the loading distribution through the trailer (fig. 17 shows the boxes stacked in trailer C).



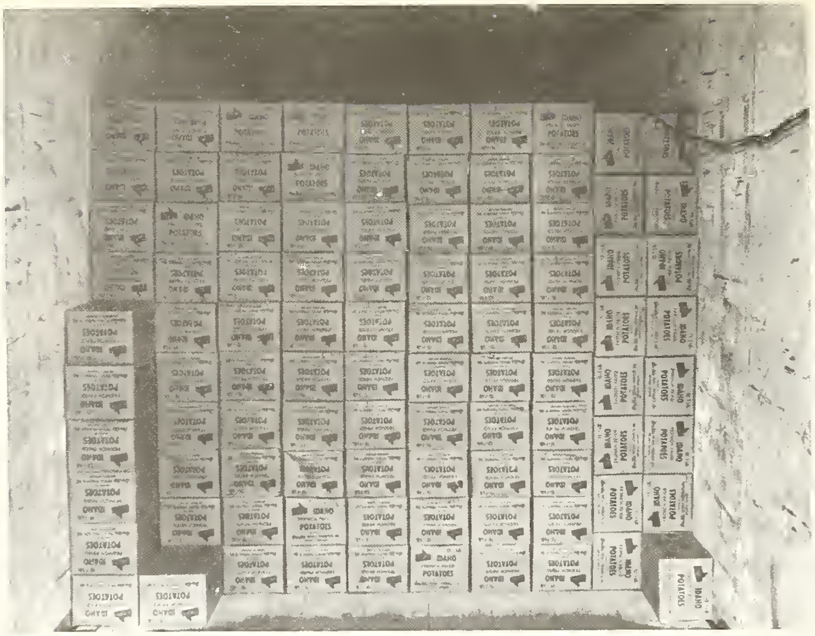
TRAILER D

U.S. DEPARTMENT OF AGRICULTURE

AMS NEGATIVE 96-61(10) AGRICULTURAL MARKETING SERVICE

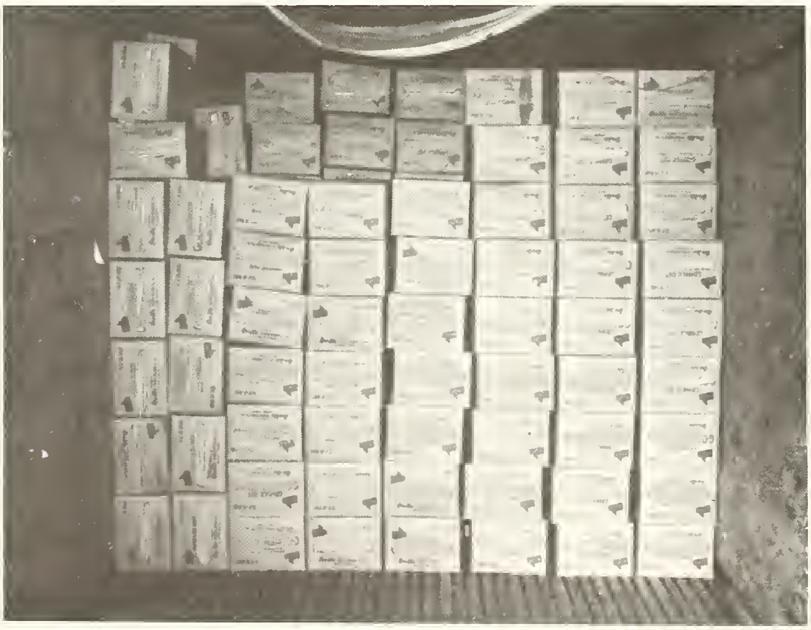
No.	POSITION
1A	Return air
2A	Blast air
3	Front, top, right side
4	Front, top, left side
5	Front, bottom, right side
6	¼ length, top, center
7	¼ length, top, left side
8	¼ length, bottom, right side
21	¼ length, bottom, center
9	½ length, top, right side
10A	½ length, top, center, air
11	½ length, top, center
12	½ length, bottom, center
13A	½ length, bottom, center, air
22	½ length, bottom, left side
14	3/4 length, top, right side
15	3/4 length, top, left side
16	3/4 length, bottom, center
23	3/4 length, bottom, left side
17	Rear, top, right side
18A	Rear, top, center, air
19A	Outside air (ambient)
20A	Rear, bottom, center, air
24	Rear, bottom, left side

Figure 10.--Locations at which air and frozen fried potato temperatures were taken in trailer D. Boxes show the loading distribution through the trailer (figs. 18 and 19 show the boxes stacked in trailer D).



BN-14727

Figure 11.--Boxes stacked at middle section of trailer C. Boxes can be tightly stacked from wall to wall and from floor to ceiling without affecting air distribution.



BN-14729

Figure 12.--Boxes stacked at rear quarter section of trailer D. Note end of canvas duct hanging from ceiling.

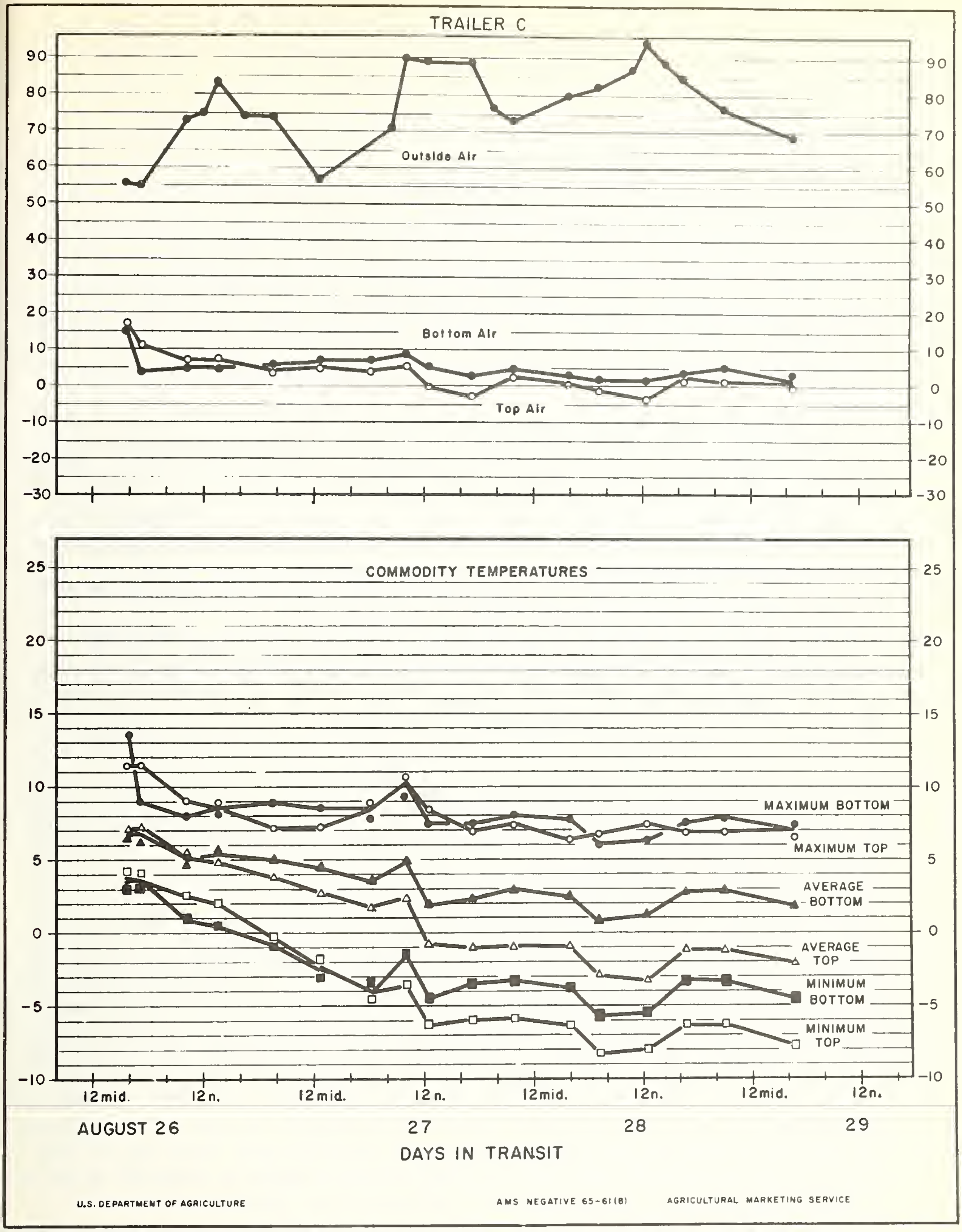


Figure 13.--Air and commodity temperatures in trailer C.

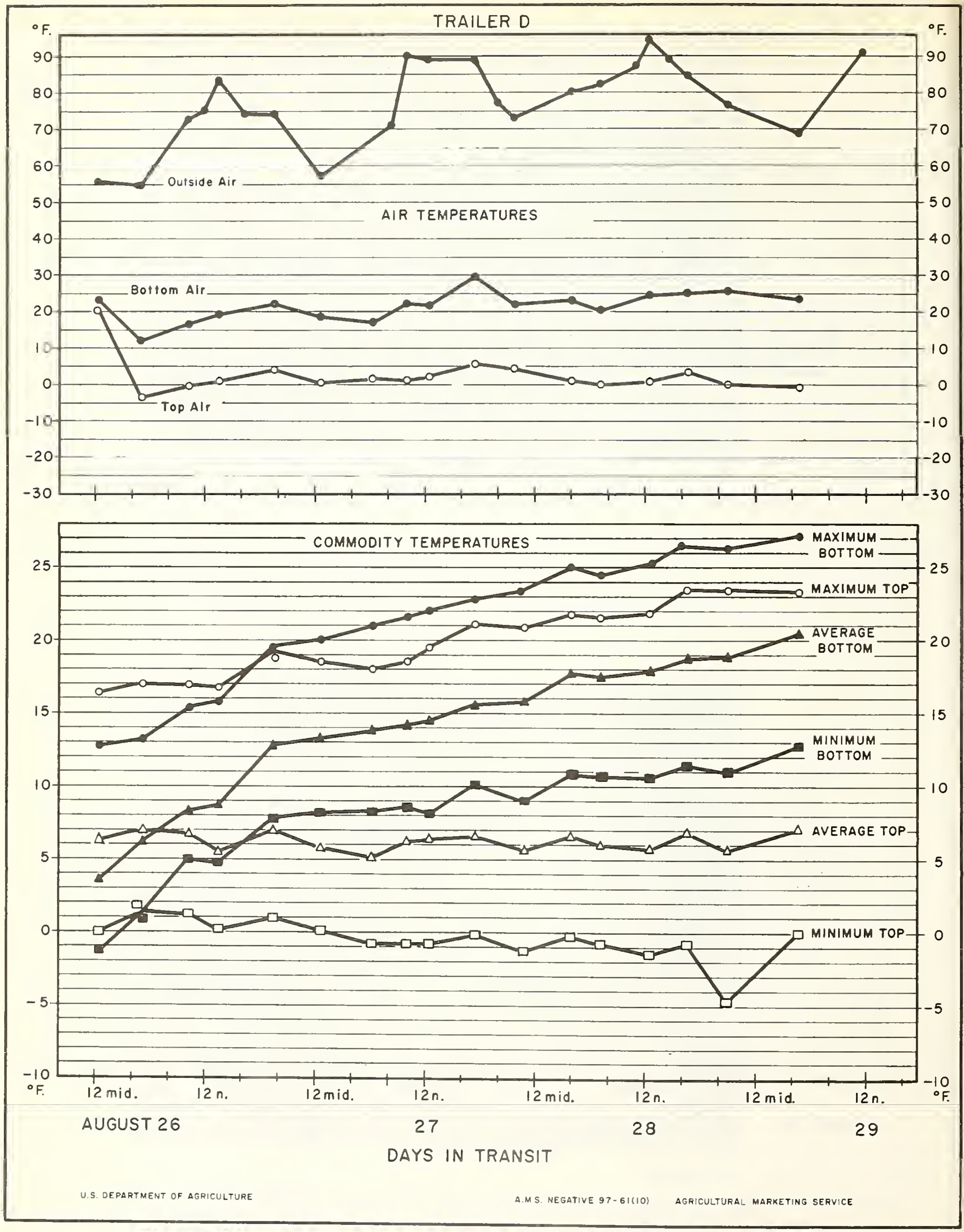


Figure 14.--Air and commodity temperatures in trailer D.

bottom-commodity temperatures rose from -1.3° to 12.8° while the minimum at the top was maintained between 1° above zero and 1° below zero throughout the test.

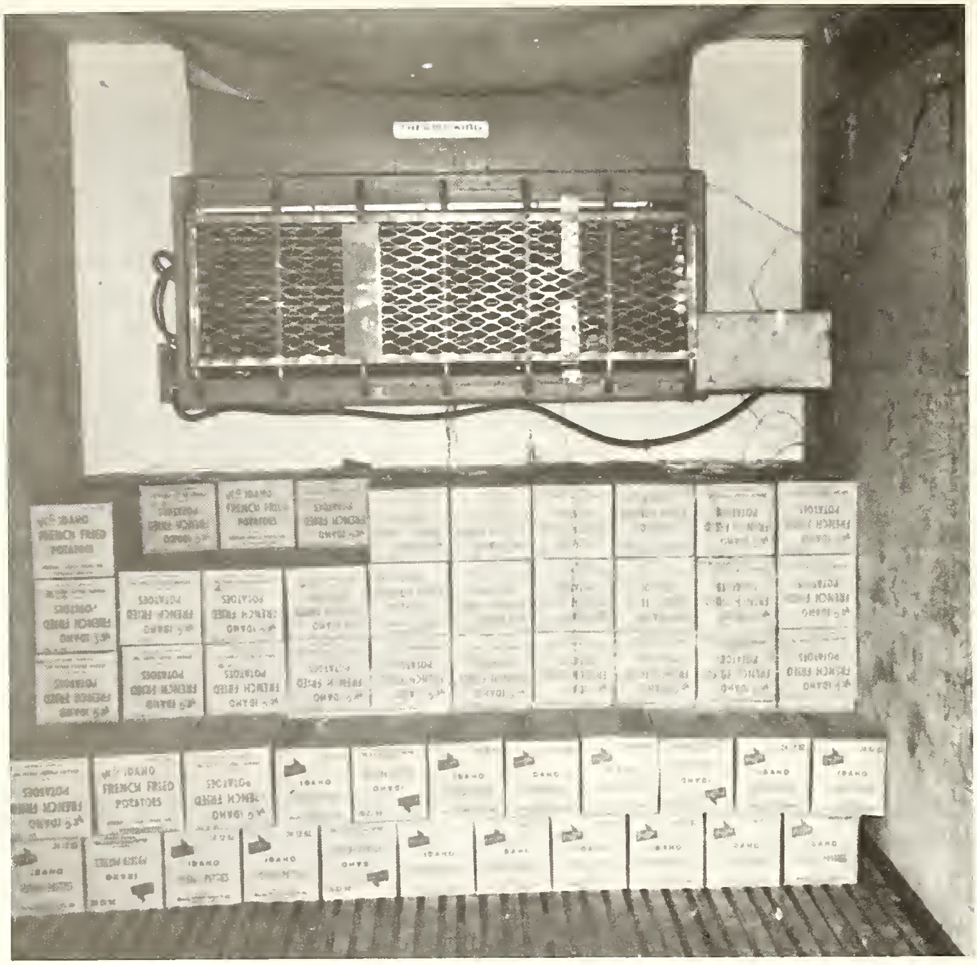
The steady increase in temperature at the bottom of the trailer indicates that refrigeration in this section of the trailer was inadequate. The fact that the temperatures continued to rise after reaching 15° emphasizes how isolated the bottom of the load was from the cold blast of air being delivered at temperatures below zero by the refrigerating unit. The evaporator section installation as shown in figure 15 permits cold air leaving the duct near the end of the trailer to flow back over the load directly to the coil. The baffle in trailer B, shown in figure 5, blocks the air from returning directly to the coil over the load. When adequate space is provided at the walls and under the floor, cold air can return down the walls and under the load, thereby cooling these sections of the trailer. The installation of a similar baffle in trailer D, the use of floor racks, and the installation of grooved sidewall lining would materially help to distribute the cold blast of air to the bottom of the load and to lower commodity temperatures. Water from the defrosting coil ran onto boxes stacked under the coil and froze. Several boxes were slightly damaged as a result during unloading. The top of the load, receiving the full benefit of the cold blast of air, also increased in temperature, however. It is doubtful therefore that this trailer, even with the modifications mentioned, would be able to maintain a zero temperature throughout a load of frozen foods in high summer temperatures.

Examination of the estimated quality loss (table 5) in the same manner as in the first test shows that the high temperatures in trailer D resulted in an exposure equivalent to 310 hours at zero. The storage life at zero was therefore reduced during the 76-hour test by about 234 hours, roughly 10 days, by exposure of the commodity to temperatures above zero.

A study of the average commodity temperatures in trailer C indicated an exposure equivalent to 103 hours at zero. The average total storage life was therefore reduced by about one day, by exposure to temperatures above zero.

FUEL CONSUMPTION IN TEST II

The fuel tanks of both trailers were filled before the refrigerating units were started. Both trailers were refueled three times during the trip to Cincinnati, and fuel consumption was calculated as the amount required to refill the tank. The refrigerating unit in trailer C required 54.4 gallons of diesel fuel during the trip and operated 40 percent of the time at high speed. Trailer D required 64.5 gallons of diesel fuel for the refrigerating unit, which operated 66 percent of the time at high speed during the test. The higher fuel consumption in trailer D, which averaged .8 gallon per hour as compared to .7 gallon per hour for the unit in trailer C, is due primarily to the fact that the unit operated a greater percentage of the time at high speed.



BN-14731

Figure 15.--Evaporator section in trailer D, showing inlet face of coil and boxes stacked below.

Table 5.--Estimated quality loss due to exposure to temperatures above zero

Trailer C				Trailer D			
Temperature range	Exposure time	Quality loss rate ratio	Equivalent time at zero degrees	Temperature range	Exposure time	Quality loss rate ratio	Equivalent time at zero degrees
	Hours	Ratio	Hours		Hours	Ratio	Hours
-2° to +2°F.	42-2/3	1	42-2/3	+3° to +7°F.	13	2	26
				+8° to +12°F.	55-1/2	4	222
+3° to +7°F.	30-1/4	2	60-1/2	13° to 17°F.	7-3/4	8	62
TOTAL	73	-	103		76-1/4	-	310

Table 6.--Fuel consumption of refrigerating units

Trailer C					Trailer D				
Location	Operating time		Fuel cons.	Average fuel cons. per hour	Location	Operating time		Fuel cons.	Average fuel cons. per hour
	At high speed	At low speed				At high speed	At low speed		
	Hours	Hours	Gal.	Gal.		Hours	Hours	Gal.	Gal.
Rawlins, Wyo.	12.4	16.7	22.2	.76	Rawlins, Wyo.	16.8	10.2	22.8	.8
Gothenburg, Nebr.	1.9	9.8	5.0	.4	Gothenburg, Nebr.	9.5	2.1	10.0	.9
Indianapolis, Ind.	15.8	16.6	22.2	.7	Indianapolis, Ind.	21.2	11.2	26.2	.8
Cincinnati, Ohio	2.2	5.2	5.0	.7	Cincinnati, Ohio	4.2	3.0	5.5	.8
Overall	32.2 (40%)	48.3 (60%)	54.4	.7		51.7 (66%)	26.5 (34%)	64.5	.8

CONCLUSIONS

The cold-wall trailer design tested was able to maintain frozen french fried potatoes below zero when the product was loaded at zero or below. The trailer, given sufficient time, was able to reduce the average temperature to zero when the commodity was loaded at temperatures near zero. During one of the 3-day in-transit tests of this trailer, the hottest box was reduced in temperature from 14° at loading to -3.6° F. at unloading.

A conventional trailer used in the second test for comparison purposes, equipped with the same model of refrigerating unit as in the cold-wall trailer, was unable to maintain satisfactory product temperatures. The installation of a baffle, such as that in trailer B, the use of floor racks, and the installation of sidewall ribbing would materially help distribute cold air and lower commodity temperatures in trailer D. The refrigerating unit on this trailer used more fuel and ran longer at high speed than its twin unit operating in the cold-wall trailer. This indicates that the cold-wall trailer with polyurethane foam insulation, was more effectively insulated.

Many measures have been taken to assure that cooling air reaches all sections of a trailer. Sidewall ribbing, floor racks, canvas ducts, cross-flow vent holes in the floor, and deeper floor grooves are examples of recent improvements in trailer design which help distribute the air around the load. But these improvements are dependent upon one another for effectiveness, and their advantages can be offset by poor loading practices. The cold-wall design, based on perimeter airflow, however, has eliminated this problem because the air distribution system built into the walls, ceiling, and floor is separated from the load and therefore not affected by the load distribution. Floor racks, required in most conventional trailers for shipment of frozen food, are not necessary in the cold-wall trailer.

Frost and condensation forming on the floor of the cold-wall trailer caused a slippery condition which required the men to take special care to avoid slipping during loading and unloading. A ridged floor design to provide a firm footing is therefore recommended.

The types of conventional trailers tested are now being replaced by cold-wall trailers in the fleet operated by one cooperating company.

Tests being conducted by the National Bureau of Standards and the U. S. Department of Agriculture will provide additional information on the amount of air space required to maintain frozen food at zero throughout the load. If the size of the air space in the walls, floor, or ceiling can be reduced, and still meet the zero degree requirements, additional cargo space will be made available.

Table 7.--Air temperatures recorded during test of trailer A from Ontario, Oreg., to Cincinnati, Ohio

Date and time	Location	Outside temp.	Air temperatures at specified locations 1/						Average top air	Average bottom air	Remarks
			Return air	Delivery air	Top air		Bottom air				
		(19)	1A	2A	10A	18A	13A	20A			
		°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	
6/16/61- 1:15 p.m.	Ontario, Oreg.	98	---	---	63	67	60	62	65	61	Refrigerating unit started.
6/16/61- 8:30 p.m.	Burley, Idaho	85	-.8	-10.4	-2.7	-2.0	-2.1	-3.3	-2.3	-2.7	Loading started at 8:35 p.m. Loading completed at 10:30 p.m. Refrigerating unit off during loading.
6/17/61- 5:00 p.m.	Little America, Wyo.	84	-5.2	-14.5	-8.7	-6.5	-.4	+2.7	-7.6	+1.2	
6/17/61- 9:15 p.m.	Rawlins, Wyo.	67	-4.5	-14.8	-8.7	-3.5	+1.5	+2.1	-6.1	+1.8	
6/18/61- 1:00 a.m.	Laramie, Wyo.	51	-6.4	-17.0	-10.5	-5.2	1.5	-0.5	-7.9	+.5	
6/18/61- 4:00 a.m.	Pine Bluffs, Wyo.	58	-4.0	-12.6	-7.8	-3.5	2.2	+0.5	-5.6	+1.3	
6/18/61-10:10 a.m.	Gothenburg, Nebr.	80	-2.6	-10.4	-6.8	-2.6	+.4	-1.8	-4.7	-.7	
6/18/61- 2:30 p.m.	Central City, Nebr.	83.5	-4.2	-.4	-2.0	+.9	+.1	5.3	-.5	+2.7	Defrosting started automatically.
6/18/61- 6:00 p.m.	Omaha, Nebr.	78.5	+3.2	-4.7	-2.3	0.8	0.1	5.3	-.7	+2.7	
6/18/61-10:00 p.m.	Winterset, Iowa	70.0	2.6	-6.0	-2.3	0.6	0.9	4.0	-.9	+2.5	
6/19/61- 1:30 a.m.	Ottumwa, Iowa	64.0	3.4	-3.6	-2.3	0.1	1.7	2.4	-1.1	+2.0	
6/19/61- 9:10 a.m.	Decatur, Ill.	81.5	2.0	-6.3	-3.6	-1.2	1.0	3.2	-2.4	+2.1	
6/19/61- 2:00 p.m.	Indianapolis, Ind.	81	-1.8	-9.7	-6.3	-2.6	1.4	3.0	-4.5	+2.2	
6/20/61- 5:00 a.m.	Cincinnati, Ohio	66.5	-4.1	-14.0	-9.5	-3.9	1.2	.7	-6.7	+1.0	

1/ See figure 4 for thermocouple locations.

Table 8.--Air temperatures recorded during test of trailer B from Ontario, Oreg., to Cincinnati, Ohio

Date and time	Location	Outside temp.	Air temperatures at specified locations 1/						Average top air	Average bottom air	Remarks
			Return air	Delivery air	Top air		Bottom air				
		(19) °F.	1A °F.	2A °F.	10A °F.	18A °F.	13A 2/	20A °F.	°F.	°F.	
6/16/61- 1:15 p.m.	Ontario, Oreg.	98	---	---	70	68		65	69	65	Refrigerating unit started.
6/16/61-10:40 p.m.	Burley, Idaho	85	.3	-9.3	-2.7	-3.9		-1.7	-3.3	-1.7	Loading began at 10:45 p.m. Refrigerating unit off during loading. Loading completed at 12:50 a.m.
6/17/61- 5:00 p.m.	Little America, Wyo.	84	9.5	-11.4	3.0	12.6		14.4	7.8	14.4	
6/17/61- 9:15 p.m.	Rawlins, Wyo.	67	.7	(-25) 3/	-7.2	28.4		20.3	10.6	20.3	
6/18/61- 1:00 a.m.	Laramie, Wyo.	51	-3.7	(-25) 3/	-10.2	27.8		18.3	8.8	18.3	
6/18/61- 4:00 a.m.	Pine Bluffs, Wyo.	58	-2.8	(-25) 3/	-8.6	31.0		20.5	11.2	20.5	
6/18/61-10:10 a.m.	Gothenburg, Nebr.	80	-13.2	-15.1	18.1	48.8		26.9	33.5	26.9	
6/18/61- 2:30 p.m.	Central City, Nebr.	83.5	20.5	-4.3	19.4	53.0		31.0	36.2	31.0	
6/18/61- 6:00 p.m.	Omaha, Nebr.	78.5	21.3	.4	27.7	47.4		29.5	37.5	29.5	
6/18/61-10:00 p.m.	Winterset, Iowa	70.0	19.8	10.5	30.4	44.5		36.9	37.5	36.9	
6/19/61- 1:30 a.m.	Ottumwa, Iowa	64.0	9.0	.2	4.0	1.9		10.3	3.0	10.3	
6/19/61- 9:10 a.m.	Decatur, Ill.	81.5	8.1	-.4	3.9	1.9		9.4	2.9	9.4	
6/19/61- 2:00 p.m.	Indianapolis, Ind.	81	8.0	-9.0	1.1	-1.7		7.9	-.3	7.9	
6/20/61- 5:00 a.m.	Cincinnati, Ohio	66.5	-3.1	(-25) 3/	-10.1	7.2		11.2	-1.5	11.2	

1/ See figure 5 for thermocouple locations.
2/ No. 13 not installed in trailer B (thermocouple not functioning).
3/ Roughly estimated, as instrumentation range was limited to -20° F.

Table 9.--Commodity temperatures recorded during test of trailer A from Burley, Idaho, to Cincinnati, Ohio

Date and time	Location	Top commodity temperatures at location: 1/												Bottom commodity temperatures at location: 1/											Overall average commodity	Overall commodity spread
		3	4	6	7	9	11	14	15	17	Max. top	Min. top	Avg. top	5	8	21	22	12	16	23	24	Max bot	Min. bot.	Avg. bot.		
		°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F. 2/	°F. 2/	°F.	°F. 2/	°F. 2/	°F. 2/
6/16/61 8:35 p.m.	Burley, Idaho	Loading started																								
6/16/61 10:30 p.m.	Burley, Idaho	Loading finished																								
6/17/61 5:00 p.m.	Little America, Wyo.	-5.5	-4.4	-4.4	-5.5	-3.5	-2.7	-2.5	-2.3	1.3	1.3	-5.5	-3.4	-5.3	-4.2	-1.2	-.8	-.4	0.5	-1.9	4.3	.5	-5.3	-1.7	-2.5	6.8
6/17/61 9:15 p.m.	Rawlins, Wyo.	-4.2	-3.7	-3.4	-4.7	-2.5	-1.9	-1.8	-1.5	2.2	2.2	-4.7	-2.5	-4.0	-2.9	0.8	0.6	1.5	2.8	-2.0	6.4	2.8	-4.0	-.2	-1.3	7.5
6/18/61 1:00 a.m.	Laramie, Wyo.	-5.0	-4.0	-3.6	-5.4	-3.2	-2.2	-2.4	-1.5	2.9	2.9	-5.4	-2.8	-4.0	-3.3	0.7	0.4	1.6	2.5	-1.8	6.5	2.5	-4.0	-.8	-1.8	8.3
6/18/61 4:00 a.m.	Pine Bluffs, Wyo.	-5.3	-4.0	-4.0	-5.0	-3.5	-2.7	-2.3	-1.6	3.4	3.4	-5.3	-3.0	-4.0	-2.6	1.2	0.4	2.3	2.8	-1.7	6.6	2.8	-4.0	+.0	-1.5	8.8
6/18/61 10:10 a.m.	Gothenburg, Nebr.	-7.3	-6.2	-6.0	-5.6	-5.3	-4.0	-4.2	-3.3	3.8	3.8	-7.3	-4.5	-6.4	-5.6	-.3	-.8	0.0	1.7	-3.0	5.7	1.7	-6.4	-1.8	-3.1	11.1
6/18/61 2:30 p.m.	Central City, Nebr.	-7.9	-6.4	-6.1	-7.8	-5.4	-4.4	-5.1	-4.6	1.9	1.9	-7.9	-5.1	-6.4	-5.7	-1.1	-2.1	-.4	0.8	-3.4	5.8	.8	-6.4	-2.3	-3.7	9.8
6/18/61 6:00 p.m.	Omaha, Nebr.	-6.1	-5.1	-5.2	-7.0	-4.8	-3.8	-4.1	-3.9	2.3	2.3	-7.0	-4.3	-5.0	-5.2	-.1	-.8	0.9	1.9	-2.1	6.9	1.9	-5.2	-1.2	-2.8	9.3
6/18/61 10:00 p.m.	Winterset, Iowa	-6.8	-5.8	-5.9	-7.6	-5.4	-4.1	-4.1	-4.3	2.4	2.4	-7.6	-4.8	-5.4	-5.6	0.4	-.9	0.4	2.2	-2.9	6.4	2.2	-5.6	-1.4	-3.1	10.0
6/19/61 1:30 a.m.	Ottumwa, Iowa	-6.1	-5.1	-5.2	-6.9	-4.8	-3.9	-4.0	-3.6	3.7	3.7	-6.9	-4.1	-5.1	-4.9	0.4	-.9	1.4	2.2	-2.9	6.9	2.2	-5.1	-1.1	-2.6	10.6
6/19/61 9:10 a.m.	Decatur, Ill.	-7.0	-5.6	-6.1	-7.6	-5.4	-4.6	-5.1	-4.5	3.7	3.7	-7.6	-4.9	-6.1	-5.6	-.2	-1.4	1.0	2.0	-3.4	6.5	2.0	-6.1	-1.6	-2.8	11.3
6/19/61 2:00 p.m.	Indianapolis, Ind.	-6.7	-5.4	-6.2	-7.5	-5.6	-4.6	-4.6	-4.0	3.3	3.3	-7.5	-4.9	-5.8	-6.0	0.6	-1.6	1.2	2.8	-2.3	5.6	2.8	-6.0	-1.2	-3.0	10.8
6/20/61 5:00 a.m.	Cincinnati, Ohio	-7.3	-5.8	-6.5	-7.9	-6.0	-5.1	-5.4	-4.7	2.8	2.8	-7.9	-5.4	-6.5	-6.0	0.2	-1.2	1.2	3.1	-3.3	4.9	3.1	-6.5	-1.4	-3.4	11.0

1/ See figure 4 for thermocouple locations.

2/ Temperature at location 24, directly over rear floor drain, considered as a nonrepresentative localized condition, therefore not considered in averages, maximums, or commodity spread.

Table 10.--Commodity temperatures recorded during test of trailer B from Burley, Idaho, to Cincinnati, Ohio

Date and time	Location	Top commodity temperatures at location: 1/												Bottom commodity temperatures at location: 1/											Overall average commodity	Overall commodity spread
		3	4	6	7	9	11	14	15	17	Max. top	Min. top	Avg. top	5	8	21	22	12	16	23	24 2/	Max. bot.	Min. bot.	Avg. bot.		
		°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.
6/16/61 8:35 p.m.	Burley, Idaho	Loading started																								
6/16/61 10:30 p.m.	Burley, Idaho	Loading finished																								
6/17/61 5:00 p.m.	Little America, Wyo.	0.3	1.3	-1.0	0.5	3.0	0.0	1.8	7.4	7.2	7.4	-1.0	1.2	4.6	5.2	2.7	11.2	4.5	3.0	6.8	7.6	11.2	2.7	5.2	3.2	12.2
6/17/61 9:15 p.m.	Rawlins, Wyo.	2.0	2.4	-0.4	1.7	3.7	0.7	3.4	8.8	12.3	12.3	-0.4	2.5	7.4	8.0	4.5	14.0	6.4	4.6	9.5	11.3	14.0	4.5	7.5	5.0	14.4
6/18/61 1:00 a.m.	Laramie, Wyo.	2.1	1.5	-1.5	1.1	1.7	1.0	2.8	8.5	14.8	14.8	-1.5	2.2	9.5	10.1	6.0	15.8	8.1	5.8	11.3	13.4	15.8	5.8	9.1	5.6	17.3
6/18/61 4:00 a.m.	Pine Bluffs, Wyo.	0.3	-0.7	-2.2	-0.8	0.6	0.2	2.0	8.5	16.0	16.0	-2.2	1.4	10.0	10.5	6.5	16.6	8.3	6.4	12.4	14.4	16.6	6.4	9.7	5.5	18.8
6/18/61 10:10 a.m.	Gothenburg, Nebr.	-1.6	-6.9	-2.4	-1.9	3.4	-.9	4.8	10.4	18.9	18.9	-6.9	1.1	10.1	10.9	7.1	17.1	8.7	7.0	13.9	15.9	17.1	7.0	10.3	5.7	25.8
6/18/61 2:30 p.m.	Central City, Nebr.	1.8	4.0	1.6	3.0	9.3	1.3	9.4	14.0	22.0	22.0	1.3	5.2	12.5	12.8	9.0	18.8	10.0	8.3	16.0	18.2	18.8	8.3	12.0	8.6	20.7
6/18/61 6:00 p.m.	Omaha, Nebr.	3.3	6.4	2.4	4.8	11.0	1.5	10.8	15.4	22.6	22.6	1.5	6.3	17.3	12.6	8.9	18.9	9.5	8.1	16.4	18.6	18.9	8.1	12.5	9.4	21.1
6/18/61 10:00 p.m.	Winterset, Iowa	8.5	11.8	6.9	9.9	15.4	5.0	14.7	18.6	24.8	24.8	5.0	10.4	15.6	15.3	11.2	21.2	11.8	9.6	18.4	20.7	21.2	9.6	14.2	12.3	19.8
6/19/61 1:30 a.m.	Ottumwa, Iowa	10.2	12.8	7.5	11.8	16.0	6.5	15.4	18.5	25.0	25.0	6.5	12.3	16.8	16.5	11.8	21.7	12.2	10.2	18.9	21.4	21.7	10.2	15.0	13.6	18.5
6/19/61 9:10 a.m.	Decatur, Ill.	7.2	8.4	3.4	7.6	9.1	5.1	11.6	13.1	18.0	18.0	3.4	7.5	15.0	16.1	10.9	21.9	11.6	10.4	19.9	22.4	21.9	10.4	14.6	11.0	18.5
6/19/61 2:00 p.m.	Indianapolis, Ind.	6.3	7.0	2.9	6.0	7.6	4.5	10.3	12.0	14.9	14.9	2.9	6.4	13.9	15.3	10.6	22.6	11.6	10.6	20.8	23.3	22.6	10.6	14.5	10.5	19.7
6/20/61 5:00 a.m.	Cincinnati, Ohio	2.7	2.1	-0.2	1.9	1.5	2.7	5.8	11.4	4.1	11.4	-0.2	2.7	11.3	14.9	9.3	23.5	12.2	12.2	22.0	24.1	23.5	9.3	14.5	8.6	23.7

1/ See figure 5 for thermocouple locations.
2/ Temperature at location 24, affected by rear floor drain, considered as nonrepresentative, therefore not considered in averages, maximums, or commodity spread.

Table 11.--Air temperatures recorded during test of trailer C from Nampa, Idaho, to Cincinnati, Ohio

Date and time (MST)	Location	Outside temp. (19)	Air temperatures at location: 1/						Average top air	Average bottom air	Remarks
			Return air 1A	Delivery air 2A	Top air		Bottom air				
					10A	18A	13A	20A			
		°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	
8/26/61 3:50 a.m.	Nampa, Idaho	55.5	11.5	4.6	7.7	27.2	5.8	24.0	17.5	14.9	Loading started at 12:25 a.m.
5:15 a.m.	Boise, Idaho	54.5	-4.7	-10.4	7.0	4.8	4.6	3.0	10.9	3.8	Loading finished at 3:40 a.m.
10:15 a.m.	Paul, Idaho	72.6	4.1	-.8	6.1	8.2	3.9	6.5	7.1	5.2	
1:35 p.m.	Pocatello, Idaho	83.6	-2.4	-9.1	6.7	7.7	5.1	5.6	7.2	5.3	
7:25 p.m.	Little America, Wyo.	74.0	-4.3	-11.6	2.8	5.5	5.5	5.6	4.1	5.5	
8/27/61 12:40 a.m.	Rawlins, Wyo.	57.0	-7.6	-14.7	2.9	8.0	6.2	7.9	5.4	7.0	
6:15 a.m.	Pine Bluffs, Wyo.	----	-7.0	-12.0	-1.1	8.9	5.7	7.9	3.9	6.8	
10:05 a.m.	Big Springs, Nebr.	90.0	-2.3	-8.4	-1.0	12.4	6.5	10.3	5.7	8.4	
12:25 p.m.	Gothenburg, Nebr.	89.0	-3.0	-7.9	-3.3	2.5	3.4	7.0	-.4	5.2	
5:30 p.m.	Central City, Iowa	89.0	-5.2	-9.8	-3.8	-1.2	3.2	2.3	-2.5	2.7	
9:50 p.m.	Council Bluffs, Iowa	73.0	-4.3	-10.1	-2.1	7.5	4.7	5.1	2.7	4.9	
8/28/61 4:00 a.m.	Winterset, Iowa	80.0	-6.0	-12.2	-.7	2.7	4.0	2.2	1.0	3.1	
7:10 a.m.	Ottumwa, Iowa	82.0	-6.6	-11.8	-3.0	.5	2.6	1.3	-1.2	2.0	
12:30 p.m.	Havana, Ill.	94.5	-5.7	-6.8	-7.7	.4	2.3	1.8	-3.6	2.0	
4:40 p.m.	Veedersburg, Ind.	84.5	-2.7	-1.6	-1.4	5.7	4.4	2.3	2.1	3.4	
9:00 p.m.	Indianapolis, Ind.	76.5	2.2	-3.6	-1.8	4.5	8.4	2.5	1.3	5.4	
8/29/61 4:45 a.m.	Cincinnati, Ohio	68.5	.0	.2	-2.7	4.0	3.7	-.8	.7	1.5	Unloading started 1st stop at 6:20 a.m.
11:35 a.m.	Cincinnati, Ohio	91.0	6.6	.4	6.7	21.5	3.6	21.5	---	---	Unloading finished 1st stop at 7:10 a.m.

1/ See figure 9 for thermocouple locations.

Table 12.--Air temperatures recorded during test of trailer D from Nampa, Idaho, to Cincinnati, Ohio

Date and time (MST)	Location	Outside temp. (19)	Air temperatures at location: 1/						Average top air	Average bottom air	Remarks
			Return air 1A	Delivery air 2A	Top air		Bottom Air				
					10A	18A	13A	20A			
		°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	
8/26/61 12:30 a.m.	Nampa, Idaho	62	27.5	21.6	21.5	19.5	12.8	33.2	20.5	23.0	Loading started at 9:10 a.m.
5:15 a.m.	Boise, Idaho	54.4	-1.1	-5.6	-3.8	-3.1	11.3	12.7	-3.5	12.0	Loading finished at 12:25 a.m.
10:15 a.m.	Paul, Idaho	72.6	-.8	-5.7	1.0	-1.8	17.3	15.4	-.4	16.3	
1:35 p.m.	Pocatello, Idaho	83.6	1.7	-3.8	-1.5	2.7	17.9	20.4	.6	19.1	
7:25 p.m.	Little America, Wyo.	74.0	-.8	-5.3	6.7	1.4	21.4	22.7	4.0	22.0	
8/27/61 12:40 a.m.	Rawlins, Wyo.	57.0	-2.9	-8.1	.1	+.5	19.0	17.5	.3	18.2	
6:15 a.m.	Pine Bluffs, Wyo.	----	8.2	8.2	-1.1	4.5	17.5	16.5	1.7	17.0	
10:05 a.m.	Big Springs, Nebr.	90.0	2.6	-1.5	-.7	3.3	21.3	22.5	1.3	21.9	
12:25 p.m.	Gothenburg, Nebr.	89.0	3.6	-.6	.7	3.6	22.3	20.5	2.1	21.4	
5:30 p.m.	Central City, Iowa	89.0	.5	-3.6	-1.5	13.1	24.0	34.7	5.8	29.3	
9:50 p.m.	Council Bluffs, Iowa	73.0	5.3	.8	1.2	7.2	18.8	25.5	4.2	22.1	
8/28/61 4:00 a.m.	Winterset, Iowa	80.0	.0	-4.5	-3.3	1.8	22.8	22.8	.7	22.8	
7:10 a.m.	Ottumwa, Iowa	82.0	-.2	-5.2	-3.3	3.0	15.8	24.3	-.1	20.0	
12:30 p.m.	Havana, Ill.	94.5	2.1	-1.7	-1.5	3.0	25.0	24.0	.7	24.5	
4:40 p.m.	Veedersburg, Ind.	84.5	.0	-4.2	-2.8	9.8	25.0	24.8	3.5	24.9	
9:00 p.m.	Indianapolis, Ind.	76.5	-1.7	-5.8	-4.7	4.7	24.7	26.6	.0	25.6	
8/29/61 4:45 a.m.	Cincinnati, Ohio	68.5	1.0	-3.7	-3.3	1.8	24.2	22.5	-.7	23.3	Unloading started 1st stop at 6:00 a.m. Unloading finished 1st stop at 8:30 a.m.

1/ See figure 10 for thermocouple locations.

Table 13.--Commodity temperatures recorded during test of trailer C from Nampa, Idaho, to Cincinnati, Ohio

Date and time (MST)	Location	Top commodity temperatures at location: 1/												Bottom commodity temperatures at location: 1/											Overall average commodity	Overall commodity spread
		3	4	6	7	9	11	14	15	17	Max. top	Min. top	Avg. top	5	8	21	22	12	16	23	24	Max. bot.	Min. bot.	Avg. bot.		
		°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.
8/26/61 3:50 a.m.	Nampa, Idaho	11.4	11.2	3.7	10.0	8.8	7.7	8.0	7.3	3.8	11.4	3.7	7.1	3.5	6.0	5.0	14.0	4.6	8.7	6.8	6.6	14.0	3.5	6.7	6.9	10.5
5:15 a.m.	Boise, Idaho	11.5	11.0	3.6	7.9	9.1	7.8	9.7	8.0	5.6	11.5	3.6	7.3	3.6	6.6	5.8	7.5	5.6	8.5	7.9	8.9	8.9	3.6	6.8	7.0	7.9
10:15 a.m.	Paul, Idaho	9.1	7.3	2.5	3.2	5.5	6.8	6.7	2.8	5.0	9.1	2.5	5.2	3.0	3.0	5.7	.8	4.9	7.8	5.8	8.0	8.0	.8	5.1	5.2	8.3
1:35 p.m.	Pocatello, Idaho	8.1	6.0	2.0	2.0	4.5	7.0	6.1	2.6	6.5	8.1	2.0	4.8	2.3	2.0	6.5	.5	5.8	8.6	5.6	8.0	8.6	.5	5.3	5.0	8.1
7:25 p.m.	Little America, Wyo.	6.2	3.7	.7	-.3	2.8	6.6	4.5	1.2	7.2	7.2	-.3	3.7	1.6	1.3	6.5	-.8	6.3	8.8	4.3	8.8	8.8	-.8	5.0	4.3	9.6
8/27/61 12:40 a.m.	Rawlins, Wyo.	4.3	1.7	-.1	-2.3	1.6	6.6	2.9	-.7	7.3	7.3	-2.3	2.7	1.3	-.3	6.3	-2.6	6.6	8.6	3.0	7.2	8.6	-2.6	4.5	3.6	11.2
6:15 a.m.	Pine Bluffs, Wyo.	2.5	.0	-.9	-4.1	-.3	5.9	3.2	-1.5	8.5	8.5	-4.1	1.8	.2	-1.9	5.2	-4.0	6.1	8.5	1.5	7.7	8.5	-4.0	3.6	2.7	12.6
10:05 a.m.	Big Springs, Nebr.	1.7	-.2	.0	-3.5	-.4	6.3	4.3	-.3	10.3	10.3	-3.5	2.4	.5	-1.5	7.2	-1.5	6.3	10.3	2.6	9.3	10.3	-1.5	4.9	3.6	13.8
12:25 p.m.	Gothenburg, Nebr.	-2.3	-3.6	-4.1	-6.3	-3.3	3.2	1.4	-2.6	8.4	8.4	-6.3	-.8	-3.7	-4.5	3.4	-3.5	3.4	7.0	-.3	7.5	7.5	4.5	1.8	.5	14.7
5:30 p.m.	Central City, Iowa	-1.8	-3.2	-3.9	-5.9	-2.3	3.1	.2	-2.8	6.9	6.9	-5.9	-.9	-2.0	-3.5	3.5	-3.5	4.5	6.7	.1	7.5	7.5	-3.5	2.3	.7	13.4
9:50 p.m.	Council Bluffs, Iowa	-1.9	-2.9	-3.6	-5.8	-3.1	2.3	1.1	-1.7	7.5	7.5	-5.8	-.9	-1.7	-3.3	5.0	-2.8	4.7	8.1	.7	7.9	8.1	-3.3	3.0	1.0	13.9
8/28/61 4:00 a.m.	Winterset, Iowa	-2.3	-3.2	-3.7	-6.3	.5	2.0	.6	-2.5	6.4	6.4	-6.3	-.9	-1.6	-3.5	3.8	-3.7	4.5	7.7	.3	7.4	7.7	-3.7	2.5	.8	14.0
7:10 a.m.	Ottumwa, Iowa	-4.6	-5.0	-5.6	-8.2	-5.3	.0	-.8	-4.3	6.7	6.7	-8.2	-2.9	-3.6	-5.7	2.0	-4.8	2.6	6.2	-1.4	5.7	6.2	-5.7	.8	-1.0	14.9
12:30 p.m.	Havana, Ill.	-4.5	-5.3	-6.0	-8.0	-7.7	-.7	-1.0	-3.2	7.4	7.4	-8.0	-3.2	-3.8	-5.5	2.8	-4.0	2.6	6.3	-.8	6.5	6.5	-5.5	1.2	-1.0	15.4
4:40 p.m.	Veedersburg, Ind.	-2.2	-3.0	-3.5	-6.2	1.0	.8	-.4	-2.5	6.8	6.8	-6.2	-1.1	-1.5	-3.2	4.0	-2.8	4.7	7.5	.3	7.0	7.5	-3.2	2.7	.8	13.7
9:00 p.m.	Indianapolis, Ind.	-2.3	-3.3	-4.0	-6.2	1.2	.9	-.3	-2.4	6.9	-6.9	-6.2	-1.2	-1.2	-3.3	4.4	-2.5	5.0	7.8	.4	7.0	7.8	-3.3	2.8	.8	14.0
8/29/61 4:45 a.m.	Cincinnati, Ohio	-2.8	-3.9	-4.6	-7.7	-1.0	.0	-.6	-3.7	7.1	7.1	-7.7	-2.0	-2.0	-4.6	3.1	3.6	4.0	7.1	-.6	6.9	7.1	-4.6	1.8	-.1	14.8
11:35 a.m.	Cincinnati, Ohio	-2.5	-3.4	-4.6	-4.0	-2.8	-.3	----	----	----	-.3	-4.6	-2.8	-2.2	-3.3	---	----	4.7	----	----	---	4.7	-3.3	1.0	-.9	9.3

1/ See figure 9 for thermocouple locations.

Table 14.--Commodity temperatures recorded during test of trailer D from Nampa, Idaho, to Cincinnati, Ohio

Date and time	Location	Top commodity temperatures at location: 1/												Bottom commodity temperatures at location: 1/											Overall average commodity	Overall commodity spread
		3	4	6	7	9	11	14	15	17	Max. top	Min. top	Avg. top	5	8	21	22	12	16	23	24	Max. bot.	Min. bot.	Avg. bot.		
		°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.
8/26/61 12:30 a.m.	Nampa, Idaho	15.0	16.3	9.8	9.0	1.8	1.7	2.0	0.0	5.5	16.3	.0	6.3	12.7	9.5	9.5	-1.3	.0	-.5	-.8	1.2	12.7	-1.3	3.6	5.0	17.6
5:15 a.m.	Boise, Idaho	15.4	17.0	9.3	9.1	4.4	2.2	1.4	3.4	7.4	17.0	1.4	7.0	13.2	12.0	10.5	1.4	3.3	2.9	3.0	4.9	13.2	1.4	6.2	6.6	15.6
10:15 a.m.	Paul, Idaho	14.9	16.9	7.2	10.1	4.6	2.2	1.2	4.2	8.1	16.9	1.2	6.7	15.4	14.3	11.3	5.0	6.3	4.2	6.9	6.6	15.4	5.0	8.4	7.5	15.7
1:35 p.m.	Pocatello, Idaho	14.7	16.7	5.0	9.7	3.5	.4	.1	3.1	10.3	16.7	.1	5.5	15.7	14.7	11.0	6.1	6.3	4.7	8.0	6.9	15.7	4.7	8.7	7.2	16.6
7:25 p.m.	Little America, Wyo.	16.7	19.3	5.4	12.8	6.2	1.4	1.0	5.2	14.7	19.3	1.0	7.1	19.5	19.5	13.8	10.3	11.0	7.8	12.8	11.3	19.5	7.8	12.8	10.0	18.5
8/27/61 12:40 a.m.	Rawlins, Wyo.	15.2	18.5	3.2	12.2	5.5	.1	.2	4.1	12.8	18.5	.1	5.8	20.0	19.8	14.8	12.1	11.2	8.2	14.5	10.3	20.0	8.2	13.3	9.5	19.9
6:15 a.m.	Pine Bluffs, Wyo.	14.2	18.0	2.2	12.2	5.2	-.8	.0	3.2	11.0	18.0	-.8	5.1	21.0	20.8	14.9	13.2	12.0	8.3	15.2	9.5	21.0	8.3	13.8	9.5	21.8
10:05 a.m.	Big Springs, Nebr.	15.2	18.5	2.3	12.3	5.3	-.7	.4	3.6	12.0	18.5	-.7	6.2	21.6	21.3	15.4	14.0	12.0	8.6	15.6	9.7	21.6	8.6	14.2	10.2	22.3
12:25 p.m.	Gothenburg, Nebr.	15.8	19.5	2.6	12.4	5.6	-.7	-.3	2.7	12.7	19.5	-.7	6.4	21.7	22.0	15.5	14.3	13.2	8.2	16.0	10.4	22.0	8.2	14.6	10.5	22.7
5:30 p.m.	Central City, Iowa	18.1	21.1	3.1	12.5	7.0	-.1	1.7	5.3	16.0	21.1	-.1	6.6	22.2	22.7	16.4	15.9	13.4	10.1	17.3	12.0	22.7	10.1	15.6	11.1	22.8
9:50 p.m.	Council Bluffs, Iowa	17.5	20.8	1.7	13.2	6.7	-1.2	-.5	4.4	15.8	20.8	-1.2	5.6	22.8	23.3	16.5	16.2	13.7	9.0	17.4	13.0	23.3	9.0	15.8	10.7	24.5
8/28/61 4:00 a.m.	Winterset, Iowa	17.7	21.8	2.8	14.7	7.4	-.4	.8	5.5	15.4	21.8	-.4	6.6	24.5	25.0	18.7	18.2	16.2	10.8	19.4	13.7	25.0	10.8	17.7	12.1	25.4
7:10 a.m.	Ottumwa, Iowa	17.2	21.5	2.0	14.2	7.3	-.8	.5	5.0	15.0	21.5	-.8	6.0	23.2	24.5	18.5	18.5	15.8	10.7	19.6	3.5	24.5	10.7	17.5	11.7	25.3
12:30 p.m.	Havana, Ill.	16.7	21.8	1.8	13.8	7.6	-1.5	.3	5.0	14.7	21.8	-1.5	5.7	24.3	25.3	18.5	18.5	16.0	10.6	20.3	15.7	25.3	10.6	17.9	11.8	26.8
4:40 p.m.	Veedersburg, Ind.	17.9	23.5	3.0	14.7	9.1	-.7	1.1	5.6	16.0	23.5	-.7	6.8	25.5	26.5	19.5	19.5	17.1	11.5	20.5	15.3	26.5	11.5	18.7	12.7	27.2
9:00 p.m.	Indianapolis, Ind.	17.8	23.4	2.6	14.4	9.5	-4.7	.5	4.7	15.2	23.4	-4.7	5.6	25.4	26.3	20.0	20.2	17.5	11.0	20.2	15.3	26.3	11.0	18.8	12.2	31.0
8/29/61 4:45 a.m.	Cincinnati, Ohio	18.0	23.3	2.9	15.3	11.3	.0	1.2	5.5	15.0	23.3	.0	7.1	26.5	27.3	20.0	22.3	19.0	12.8	21.9	17.1	27.3	12.8	20.5	13.8	27.3

1/ See figure 10 for thermocouple locations.

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